THE GROWING THREAT OF URBAN FLOODING: A NATIONAL CHALLENGE

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University of Maryland, College Park

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Texas A&M University, Galveston Campus

Center for Texas Beaches and Shores

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BISMARK, NORTH DAKOTA, PHOTO BY DAVID VALDEZ/FEMA

CONTENT


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COVER: Heavy rains produce neighborhood flooding. Kenilworth, Illinois, 2013. Source: Village of Kenilworth.

THE GROWING THREAT OF URBAN FLOODING

GONZALES, LOUISIANA, PHOTO BY J.T. BLATTY/FEMA

Over the past decade, major hurricanes and extreme storm events have wreaked havoc on many urban areas throughout the United States. While the major storms of 2017 and 2018 (Florence, Harvey, Maria, and Irma) will be remembered as hurricanes, in many cases it was the intense rainfall that brought urban areas to a standstill, overwhelming homes and transportation arteries with flood water.

Aging and inadequate infrastructure, coupled with rapid land development, increased the amount of storm runoff to already stressed drainage systems, creating pockets of flooding in ill-equipped and vulnerable neighborhoods. In many communities, a lack of resources, a division of responsibilities among various departments, and a reluctance to deal with the impacts of increasingly intense precipitation and climate change has slowed progress in meeting the challenges of urban flooding.

In 2016, the Center for Texas Beaches and Shores at Texas A&M University, Galveston Campus and the Center for Disaster Resilience at the University of Maryland initiated a joint study to determine the extent and consequences of urban flooding in the United States and explore what actions might be taken to mitigate this flooding in the future. Center researchers analyzed available data concerning urban flooding, surveyed municipal flood and stormwater managers, and met with professionals whose disciplines intersect with urban flooding at the local, state, and national level. This report presents the results of that study, addressing issues that affect urban flood risk reduction, examining critical challenges, and offering recommendations for action.

THE STUDY TEAM REACHED THE FOLLOWING CONCLUSIONS:

1. **In much of the United States, urban flooding is occurring and is a growing source of significant economic loss, social disruption, and housing inequality.** Extensive suburban development that creates higher flood flows into urban areas, aging and frequently undersized infrastructure in older sections of communities, an inability to maintain existing drainage systems, increases in intense rainfall events, and uncoordinated watershed management all contribute to these increases in urban flooding.

2. **The growing number of extreme rainfall events that produce intense precipitation are resulting in—and will continue to result in—increased urban flooding unless steps are taken to mitigate their impacts.** The 2017 National Climate Assessment concluded that "heavy downpours are increasing nationally, especially over the last three to five decades…[and that]… increases in the frequency and intensity of extreme precipitation events are projected for all U.S. regions."

3. **Communities across the nation are facing similar challenges with urban flooding.** However, the unique hydrological, physical, and social characteristics of these communities mean solutions are best developed locally. While the magnitude of urban flooding challenges merit federal guidance and support when needed, responsibilities must rest primarily at the local level.

4. **While primary responsibility for mitigation of urban flooding rests with local governments, the division of responsibilities among federal, state, regional, local, and tribal governments for urban flood and stormwater management are not clearly defined.** Responsibilities are diffused and lack the collaboration and coordination necessary to address the technical and political challenges that must be faced.

5. **Many of the urban wastewater and stormwater systems that provide the backbone of urban flood mitigation are in poor condition and—in some locations—are inadequate and in need of strong support.** The human and fiscal resources necessary to address urban flooding are not generally available at the levels required.

6. **At the federal level, there is no agency charged with oversight of federal support of urban flood mitigation-related activities.** While primary responsibility for urban flood mitigation rests at the local level, the federal government is already operating programs for riverine and coastal flood risk reduction and stormwater management; these programs are inextricably linked to urban flooding.

7. **The economic and social impacts of urban flooding are generally not well known and understood by many public officials and the unaffected public.** Social vulnerabilities and inequities in disaster recovery for low-income populations are not being fully addressed.

8. **Governments, at all levels, have not provided effective means to communicate risks to those in urban flood-prone areas.** A significant number of these areas are not identified by maps produced under the Federal Emergency Management Agency National Flood Insurance Program, and actions by those responsible for urban flood mitigation are needed to delineate these areas. Communication of flood risk is often seen by public officials and developers as a negative.

9. **Many homeowners and renters living and working in areas affected by urban flooding do not understand that they can take steps to significantly reduce their property's vulnerability, and many lack the resources and support necessary to carry out such actions.** Information on how a resident can reduce their property's flood risk is not accessible or well-articulated.

10. **Data—covering insurance claims, assistance, and loans for flood mitigation—are not easily available or shared with local decision makers, researchers, and the residents themselves.** More accessibility and availability of data is critical to effective response, recovery, and long-term mitigation of flood events. This data must be provided in an easily interpreted and spatially identifiable format.

THE STUDY TEAM RECOMMENDS THAT:

1. **Governors, tribal leaders, and regional and municipal officials should review the current responsibilities for oversight of urban flooding mitigation, as well as flood, water, wastewater, and stormwater management in their jurisdictions; provisions, as appropriate, should be made to ensure efficient and effective multi-jurisdictional planning and operation of these activities and services on a geographic scale that matches the problems being addressed.**

2. **The administration, in coordination with Congress, should convene a forum of representatives from state and local governments, Indian tribes, nongovernmental organizations, and the public to develop a national "suite of actions" to mitigate urban flooding and identify responsibilities at each level of government.**

CHAMPAIGN, ILLINOIS, PHOTO BY C. ELIANA BROWN

3. **The administration, in coordination with Congress, should assign one federal agency to provide interim oversight of federal support of urban flood mitigation activities, the development of the national forum, and the preparation of a post-forum report for the administration, Congress, the states, municipalities, and tribes.**

4. **Attention should be given at all levels of government to ensure that efforts to mitigate urban flooding reach areas that have the highest risk of flooding and cross all economic and social levels and that locally supported steps are taken to incentivize individual homeowner mitigation efforts.**

LOW IMPACT DEVELOPMENT, PHOTO BY VIRGINIA SOIL AND WATER CONSERVATION DISTRICT

5. **In coordination with ongoing efforts to ensure that those at risk of flooding are aware of their vulnerabilities, FEMA, USACE, NOAA, USGS, EPA, and HUD, in collaboration with urban flood communities, should integrate urban flood risk communication outreach into their ongoing programs for riverine and coastal flooding and ensure that analysis of future conditions should include the impacts of climate and weather and future development.**

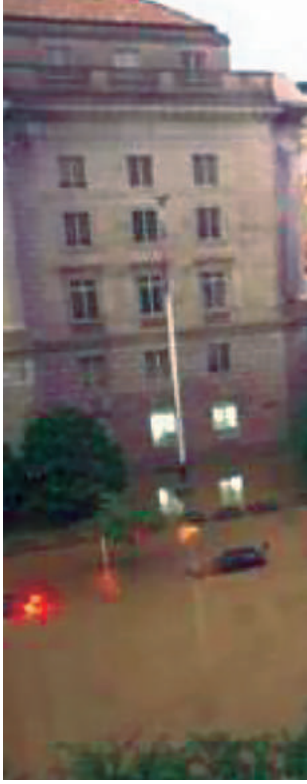
6. **States should consider integrating urban flood risk communication, mapping, and risk disclosure measures into real estate transactions in urban flood areas.**

7. **The Congress and the administration, in coordination with state governors, regional, local, and tribal officials, should develop appropriate mechanisms at the federal, state, and local level to fund necessary repairs, operations, and upgrades of current stormwater and urban flood-related infrastructure.**

8. **Congress should direct the administration to establish a risk identification grant program that enables communities to develop effective means of identifying the risks they face from urban flooding.**

NEW HARTFORD, IOWA, PHOTO BY GREG HENSHALL/FEMA

9. **The administration should support continued research into urban flooding to ensure that the full extent of the threat is identified and that steps are taken to formulate solutions to policy and technical issues.**



I. URBAN FLOODS: THE NATION'S HIDDEN CHALLENGE

THE INCREASING THREAT TO OUR COMMUNITIES

While riverine and coastal floods continue to pose a major threat to communities across the United States, causing billions of dollars of losses every year, urban flooding, which is often neglected in community planning and preparedness, is also having significant impacts. Increasing rainfall, combined with rapid land use change and development in flood-prone areas, has amplified the adverse economic and human impacts in recent years. Never have the repercussions of storm events driven by both coastal surge and rainfall been so damaging to local communities. Losses from acute and chronic floods have become especially problematic in low-lying urban areas, where stormwater infrastructure deterioration, population growth, and development have accelerated over the last several decades. Unfortunately, limited information is available about the extent and consequences of urban flooding. In much of the country, little is being done to address these consequences and develop plans to address problems before they get worse. This report seeks to provide information that will help governments and the public better understand the challenge of urban flooding and act on it.

MICHIGAN UNDERWATER

On August 11, 2014, heavy rains moved into Southeast Michigan and the metropolitan Detroit area, including the city of Flint and the Saginaw Valley. Four to six inches of rain fell in a four-hour period, and over 75,000 homes and businesses suffered damage. The intensity of the rainfall overwhelmed the area's drainage systems, which were in poor condition.[1] The estimated total damages exceeded $1.8 billion, making it the costliest U.S. flood event in 2014 and accounting for 60% of flood damage nationwide, according to the National Weather Service. Seventeen percent of the impacted residences were owned by low-income households and 13% by elderly households.

FIGURE 1. FLOODED HOMES RESULTING FROM AN INTENSE RAINFALL EVENT, AUGUST 2014. SOURCE: MICHIGAN STATE POLICE.

Between 2007 and 2011, urban flooding in Cook County, Illinois resulted in over 176,000 claims or flood losses, at a cost of $660 million dollars. Seventy percent of 115 respondents to a survey conducted by the Chicago-based Center for Neighborhood Technology (CNT) indicated that they had flooded three or more times during this five-year period; 20% had flooded 10 or more times.[2] In 2016, the city of Baton Rouge was inundated by an estimated 1,000-year rainfall event that flooded 48,000 structures and created over $1 billion in property damage. City officials pointed to the need to expand the community stormwater capacity.[3]

Urban flooding occurs not just in major cities but in the majority of U.S. communities, large and small. For smaller communities, the impact is more severe because they frequently lack the resources to deal with significant rainfall events and, because of their size, do not rise to the level of losses associated with federally-supported disaster assistance. In May 2018, Ellicott City, Maryland was hit by a second estimated 1,000-year rainfall event in two years and was once again subject to more than a billion dollars in damages. In June 2018, eight inches of rain fell in four hours on Ankeny, Iowa, flooding over 2,000 homes. The assessment of losses has not been completed.[4]

Urban flooding not only causes major property damage, it is also responsible for fatalities and injuries. Each year, people die while trying to move cars through deep or fast-moving water in streets. In July 2018, the tenant of a basement apartment in Englewood, Colorado was trapped in her apartment by waters from a major downpour and drowned. Stories of similar incidents or near misses are frequent.[6]

OUR NATION'S CAPITAL

In June 2006, heavy rainfall over downtown Washington, D.C. caused major flooding in the Federal Triangle, the area between Pennsylvania and Constitution Avenues and the home of many major government agencies. As a result, the headquarters building of the Internal Revenue Service was shut down for six months; areas in the National Archives Building, the Departments of Justice and Commerce, and the Environmental Protection Agency were also damaged. Total damages to the government buildings and adjacent commercial properties were estimated in the tens of millions of dollars. No judgment was made as to the potential damages to the iconic structures and their contents. Again, inadequate drainage was given as the cause of the flooding.[5]

FIGURE 2. FLOODING AT CONSTITUTION AVENUE AND 10TH STREET NW, WASHINGTON, D.C., JUNE 2006. THE INTERNAL REVENUE SERVICE IS ON THE LEFT; THE DEPARTMENT OF JUSTICE ON THE RIGHT. SOURCE: U.S. GENERAL SERVICES ADMINISTRATION.

FROM THE COMMUNITY

(Comments from respondents of this study's national survey of flood and stormwater professionals.)

"The Village of [redacted] is a prime example of a community that faces urban flood issues. [Redacted] is not adjacent to a major tributary receiving water but has several isolated neighborhoods that face significant urban flooding during even moderate events. While these locations are few, the impact felt by these residents is massive. Although these are small areas within the community, the Village continues to struggle with the concept of allocating major capital funding to help only a small contingent of the community. Due to this struggle, these areas continue to go unmitigated."

Flood issues are traditionally associated with riverine and coastal areas, but increasing attention is being given to urban flooding, where flood risk is more a function of the human-built environment. Population growth and associated development in metropolitan areas along the coast, combined with aging stormwater infrastructure and changing weather patterns, have given rise to an urban-specific flood problem of national importance. In this new category of flooding, risk and impacts are no longer tied to the Federal Emergency Management Agency (FEMA)-defined floodplains. Instead, significant flood losses can occur miles from a delineated floodplain where these urban losses are embedded in a highly developed landscape. Riverine and coastal floods occur when the river rises out of its banks, or coastal tides and surges rise above the shoreline. Flood flows can stretch to the highest ground in the vicinity, yet the FEMA-identified regulatory floodplains only include limited areas of the total floodplain. Low spots in the floodplain create areas for rainwaters to accumulate. Heavy rainfalls can exceed a stormwater system's ability to move the rainfall from inland areas to the river for eventual flow to larger rivers or coasts (Figure 3). Given that the urban footprint in the United States is predicted to increase from 3.1% to 8.1% from 2000 to 2050[7], especially in coastal regions, urban flood losses will continue to mount and present an important national policy problem for years to come.

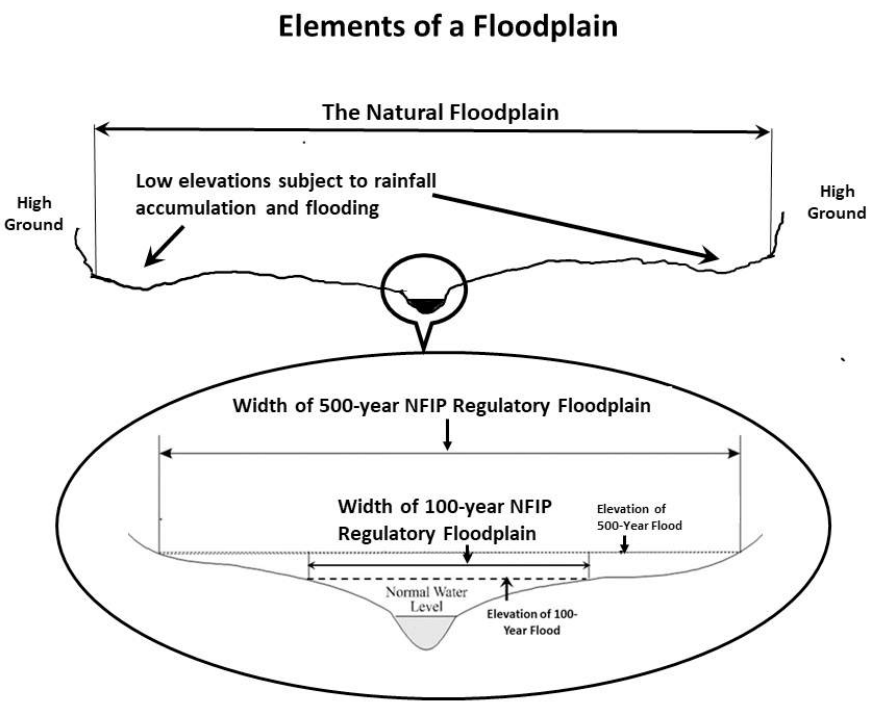


FIGURE 3. THE 100-YEAR FLOODPLAIN REPRESENTS AN AREA WHERE THERE IS A 1% ANNUAL CHANCE THAT A FLOOD WILL OCCUR, AND A 500-YEAR FLOOD IS WHERE THERE IS A 0.2% CHANCE EACH YEAR OF SUCH AN EVENT. SOURCE: CENTER FOR DISASTER RESILIENCE, UMD.

THE EFFECTS OF FLOODS ACROSS THE UNITED STATES

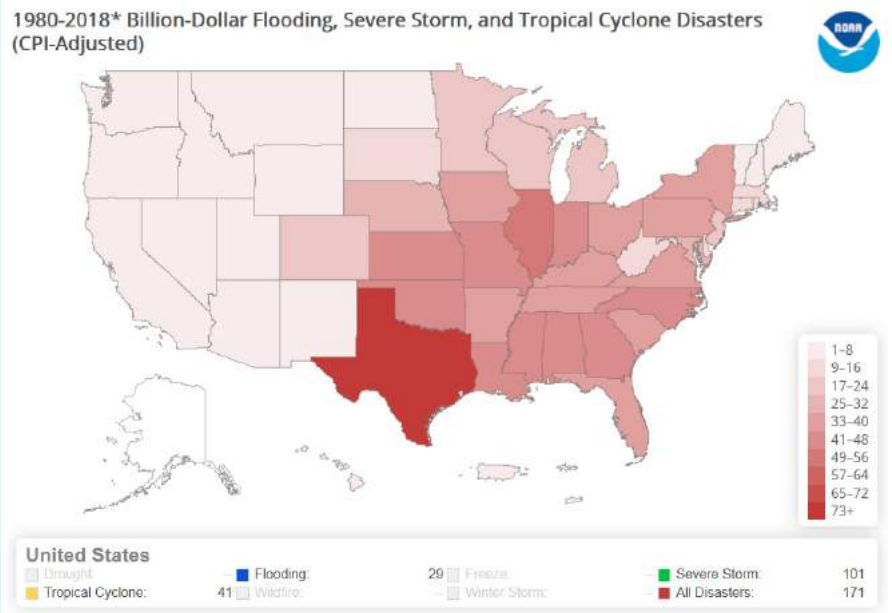
In 2017, New York University's Fuhrman Center reported that "an average of 15 million people nationwide lived in the 100-year floodplain in 2011-2015, representing nearly 5% of the nation's population. More than 30 million people—nearly 10% of the nation's population—lived in the combined 100- and 500-year floodplain during this period. Two-thirds of the population living in the nation's combined floodplain lived in Texas or New York." Figure 4 illustrates billion-dollar flood, severe storm, and cyclone disasters from 1980-2018. The National Weather Service (NWS) reports that between 1984 and 2013, flood losses in the United States from freshwater sources were estimated to be $238 billion (7.95 billion/year adjusted to 2014 inflation).[8] The estimate does not include damages from coastal storm surge events (e.g., Sandy and Katrina). Most of the statistics on flood losses in the United States are developed from information gathered in response to significant flood events or as a result of claims submitted against the National Flood Insurance Program (NFIP) (Figure 5).

There is very little data identifying where urban area flooding (not connected to rivers or coastal areas) is taking place in the United States, the consequences associated with this flooding, or the profile of those who have been affected. Data from commercial insurance policies are not normally publicly available, so claims made against those policies rather than the NFIP are not spatially defined for use by the public or by public officials.

FROM THE COMMUNITY

"It's important to raise the awareness of "localized" floodplain management. Too often developers, builders, and engineers only consider the FEMA designated floodplains."

FIGURE 4: 1980-2018* BILLION-DOLLAR FLOODING, SEVERE STORM, AND TROPICAL CYCLONE DISASTERS (CPI-ADJUSTED). SOURCE: NOAA NATIONAL CENTERS FOR ENVIRONMENTAL INFORMATION (NCEI) U.S. BILLION-DOLLAR WEATHER AND CLIMATE DISASTERS (2018), NCDC.NOAA.GOV/BILLIONS/MAPPING.



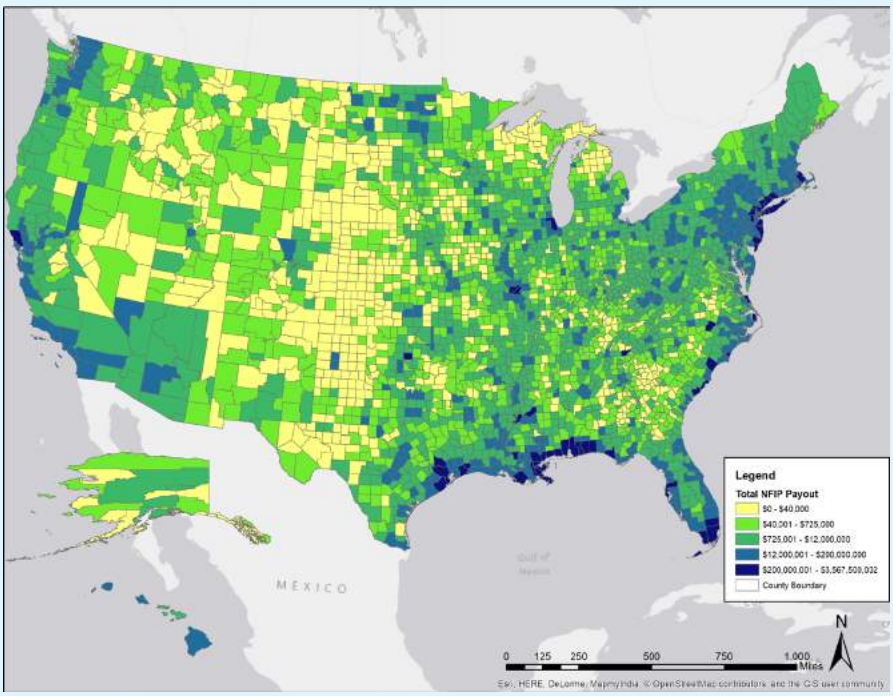


FIGURE 5. NFIP CLAIMS PAYOUTS BY COUNTY, 1974-2014. SOURCE: FEMA NFIP; MAP BY CENTER FOR TEXAS BEACHES AND SHORES, TEXAS A&M (CTBS), 2018.

WHAT IS URBAN FLOODING?

FIGURE 6. NEIGHBORHOOD FLOODING FOLLOWING INTENSE RAINFALL, SAN JOSE CALIFORNIA, FEBRUARY 2107. SOURCE: SAN JOSE FIRE DEPARTMENT.

While infrequent major storm events and floods have created historic riverine and coastal disasters, urban flooding, which occurs frequently and ubiquitously, is constantly gnawing at the fabric of communities. The total cost of urban flooding has not been accurately recorded for several reasons: such floods occur frequently; they are scattered in neighborhoods throughout communities; they do not rise in total economic costs to the level of major events; and they are often not reported. Yet these events inflict significant economic and social damage on groups that have the least ability to deal with them. Cars and household items, in the absence of liquid assets, are frequently their most valuable possessions.

FEMA defines urban flooding as "the inundation of property in a built environment, particularly in more densely populated areas, caused by rain falling on increased amounts of impervious surfaces and overwhelming the capacity of drainage systems. It excludes flooding in undeveloped or agricultural areas. It includes situations in which stormwater enters buildings through a) windows, doors, or other openings; b) water backup through pipes and drains; c) seepage through walls and floors." The definition has been expanded to include specific issues, such as sewer water backing up into homes, water seeping through foundation walls, clogged street drains, and overflow from sound walls, roads, or other barriers that restrict stormwater runoff. In 2015, at the direction of the state legislature, the Illinois Department of Natural Resources conducted a study of urban flooding within the state, characterizing such flooding "...by its repetitive, costly, and systemic impacts on communities, regardless of whether or not these communities are located within formally designated floodplains or near any body of water. These impacts include damage to buildings and infrastructure, economic disruption, and negative effects on health and safety."[9]

FROM THE COMMUNITY

"The areas being impacted by urban flooding are those that were built prior to our agency's existence. The system was taken over from the cities and standards were changed to reduce impacts due to urban flooding and continue to change to mitigate the climate impacts. While a Corps system protects the community from stream flows up to the 200-year event, urban flooding continues due to the magnitude of storms that exceed the capacity of the urban storm drainage system. Very few in the community recognize this reality."

FIGURE 7. BRIDGEVILLE, PENNSYLVANIA RESIDENTS MUCK OUT THEIR BASEMENT AFTER A FLASH FLOOD. SOURCE: FEMA NEWS/PHOTO BOB MCMILLIAN.

II. ANALYZING URBAN FLOODING

The analysis in this report is based on a national survey of municipal flood and stormwater managers and professionals working in these fields; the examination of available data from federal agency programs, commercial organizations, and nongovernmental organizations; and nationwide outreach efforts to determine the nature and extent of urban flooding.

83%

of respondents indicated they had experienced urban flooding in their communities (n=388).

46%

indicated that urban flooding occurred in numerous areas or most areas in these communities (n=325).

85%

had experienced urban flooding outside the Special Food Hazard Area. 15% had not (n=296).

51%

of the communities had been affected by moderate or larger urban floods (n=325).

65%

of respondents reported that less than 10% of moderate urban flood damages in their communities were covered by insurance under the the National Flood Insurance Program (n=242).

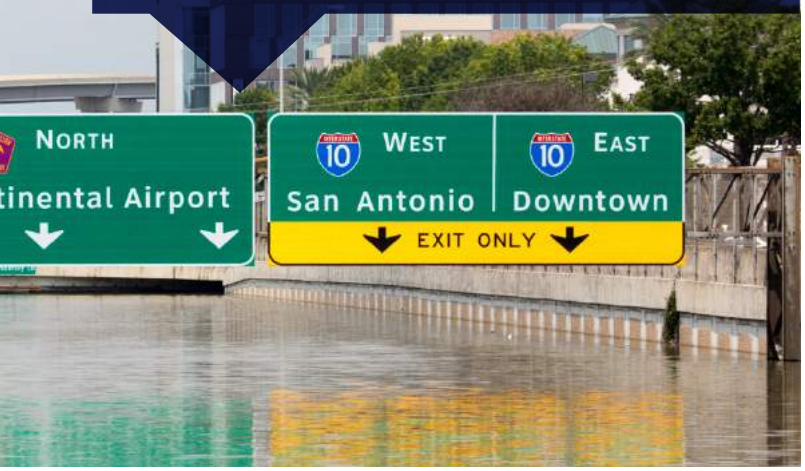
HOUSTON, TEXAS AFTER HURRICANE HARVEY

NATIONAL SURVEY

To gather information about the nature and extent of urban flooding, the study team identified and sent e-mail requests to over 1,000 stormwater and floodplain management practitioners in both municipalities and organizations that work with municipalities. Over 700 individuals responded to the survey, representing or having knowledge of over 350 municipalities. Respondents represented 48 states (exceptions were professionals in Wyoming and Montana, who were contacted by telephone). The respondents represented large, moderately-sized, and small communities. In addition, respondents provided 103 general comments on the topic as well as 883 comments or explanations to supplement answers to specific questions. The average number of responses to non-demographic questions was 306; however, the same individuals did not answer every question. In listing survey results, the percentage of respondents providing a given answer are shown against the number of respondents who provided answers to that question (e.g. n=X). A copy of the survey, including extracts from survey comments, can be found in Volume 2 of this report, available at cdr.umd.edu/urban-flooding-report.

FROM THE COMMUNITY

"Our county is becoming more & more developed, and we have a well-developed stormwater program to address much of this. However, we lack the urgency to do anything about our current stormwater management issues for a number of reasons: 1) political will is not supportive; 2) Most of the flooding occurs in low-income areas; 3) Flooding is not widespread when it does occur (like the 2010 [redacted] flood that affected all income levels and thus prompted an aggressive, progressive policy shift that requires low impact development); and 4) the general population does not understand stormwater infrastructure and/or are unwilling to maintain the part of the system that is on their property (easements, swales, storm drains, etc.), which cuts the streams off from their floodplains and exacerbates flooding conditions, now even in times of moderate rain events. Whew!"



DATA ANALYSIS

In determining where urban flooding has occurred across the country and its impacts, multiple data sets were used with a focus on available geospatial data, which more accurately identified the location and consequences of urban flood events.

One of the significant limitations in analyzing floods losses or government expenditures is that individuals and communities are only eligible for some programs when a federal disaster declaration has been made by the president. The result of this restriction is that smaller, chronic flood events or flooding in neighborhoods with less expensive homes may not be represented in the data.

PRINCIPAL DATA SOURCES

- The National Flood Insurance Program, 1972-2017. Insurance claims and policies: residential building damage (up to $250,000) and insured contents damage (up to $100,000).
- Small Business Administration loans (2004-2016) to individuals and businesses located in a county where a federal disaster has been declared.
- FEMA's Individual Assistance grants, 2004-2016, for disasters classified as floods; provides grants up to $33,000 (adjusted each year) to homeowners and renters when a federal disaster has been declared.
- FEMA/HUD Hazard Mitigation Grant Program property buy outs, 1998-2013.
- FEMA Public Assistance grants, 1992-2017; costs to remove debris, fund emergency protective measures, and repair/replacement of disaster-damaged facilities that are publicly owned. Provided to local government and some non-profits where a federal disaster has been declared.
- U.S. Census, 2010.
- NOAA Hydrologic Information Center—flood loss data.
- U.S. Census Bureau American Community Surveys.

OUTREACH

Over two years, the study team traveled extensively throughout the United States, connecting with professionals in the stormwater and flood management fields, public officials with responsibility for infrastructure management, and officers and committee members of professional associations. The team made presentations at meetings of government agencies and professional organizations and conducted focus groups. They met with senior officials of the Environmental Protection Agency (EPA), the U.S. Army Corps of Engineers (USACE), FEMA, the National Oceanic and Atmospheric Administration (NOAA), and the U.S. Department of Housing and Urban Development (HUD), as well as staff of members of Congress. The team was also able to meet with academics and practitioners from abroad to discuss the challenges they faced in their countries.

OBTAINING THE DATA

As indicated earlier in the report, neither the federal or state governments track urban flooding as it occurs or over time. Some communities maintain records of flooding, but they are generally inconsistent in both time and content. There is no national data repository that is collecting such information. The bits of data that are collected are not collected in a standard format, vary in geospatial specificity, and exist across the records of multiple organizations. Information collected by commercial organizations, such as insurance companies, is not publicly available and is generally protected by privacy restrictions that limit their use by even government and academic researchers. NOAA, as indicated earlier, maintains a record of significant weather events and their location; it includes supplemental information on impacts of weather events, as well as information on damages, fatalities, and injuries that occur as a result. To find out where urban flooding is taking place, the study team used the survey to garner information from those representing urban areas, participated in meetings and focus groups, met with selected municipalities, and reviewed flood-related literature and the media to identify where urban flooding has been reported or discussed. The team also analyzed datasets relevant to national and urban flooding, which identified conditions that reflected a probability that urban flooding is occurring in specific areas.

III. WHERE DOES URBAN FLOODING OCCUR?

Eighty-three percent of survey respondents (n=320) indicated that urban flooding was occurring in their associated communities. Since the respondents represented 48 states, it is clear that such events are occurring nationally (representatives of the two states that did not respond to the survey indicated telephonically the presence of urban flooding in those states). Discussion with participants at major stormwater and flood conferences, contact with non-governmental organizations, and participation in focus groups confirmed the widespread nature of urban flooding and that urban flooding was affecting both large and small communities. A review of news alerts from online sources using the search term "urban flooding" found that reports of multiple urban flood events occurred almost daily and were geographically distributed across the country.

Since 1993, the NOAA flood loss database has included descriptive information on flood events from regional field office reports of the National Weather Service (NWS). Flood loss submissions provide state and county location of the event as well as dollar losses and fatalities connected with the event. Using the terms "urban flooding" and "street flooding" to screen descriptive entries in the database, the study team found 3,663 entries either meeting the criteria or relating to what likely were urban flood events. These events were distributed across the entire United States (Figure 8). These basic searches helped confirm the information garnered from the survey, outreach activities, and media reports. States differed in both the distribution of storm events and how individual NWS regions reported events.

FIGURE 8. NUMBER OF URBAN FLOODING OBSERVATIONS BY STATE (1993-2017). SOURCE: NOAA; MAP BY CENTER FOR TEXAS BEACHES AND SHORES, TEXAS A&M (CTBS), 2018.

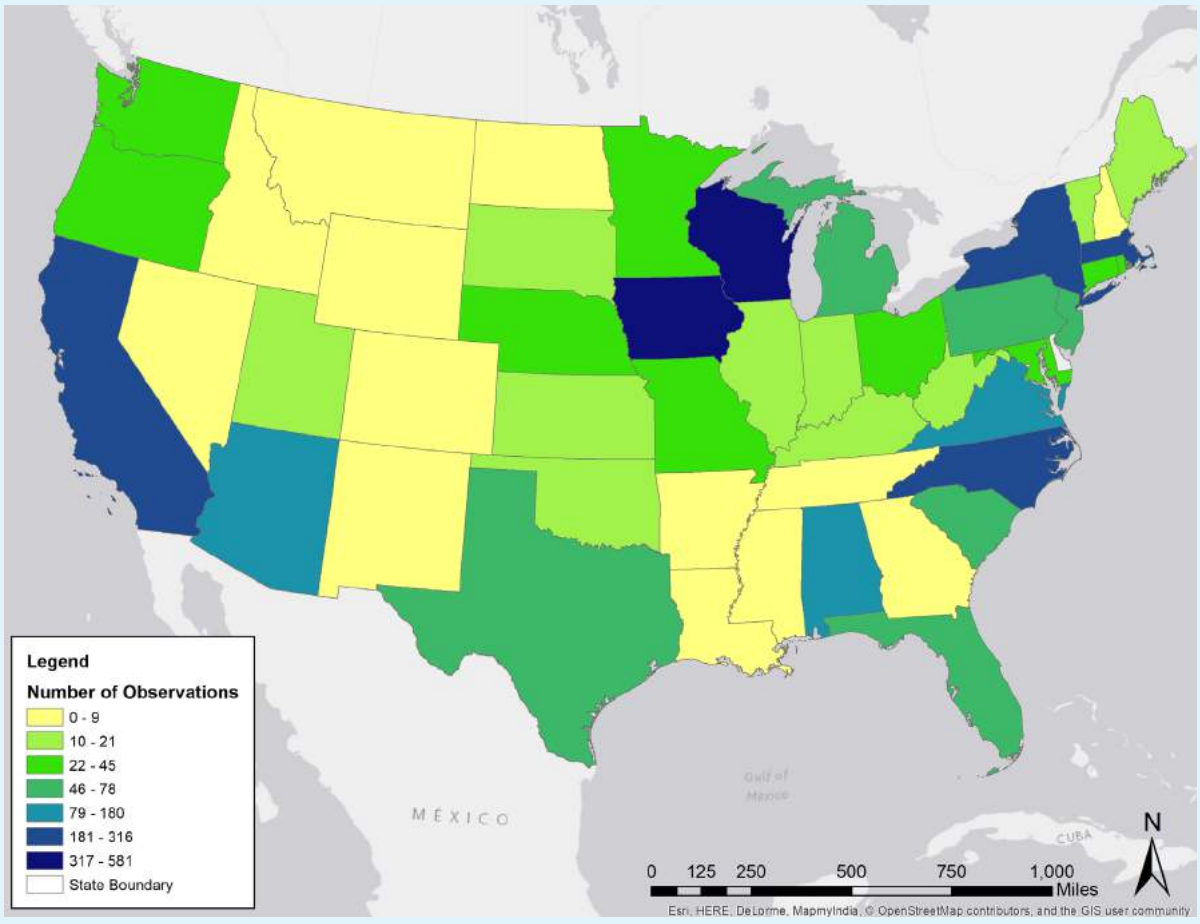
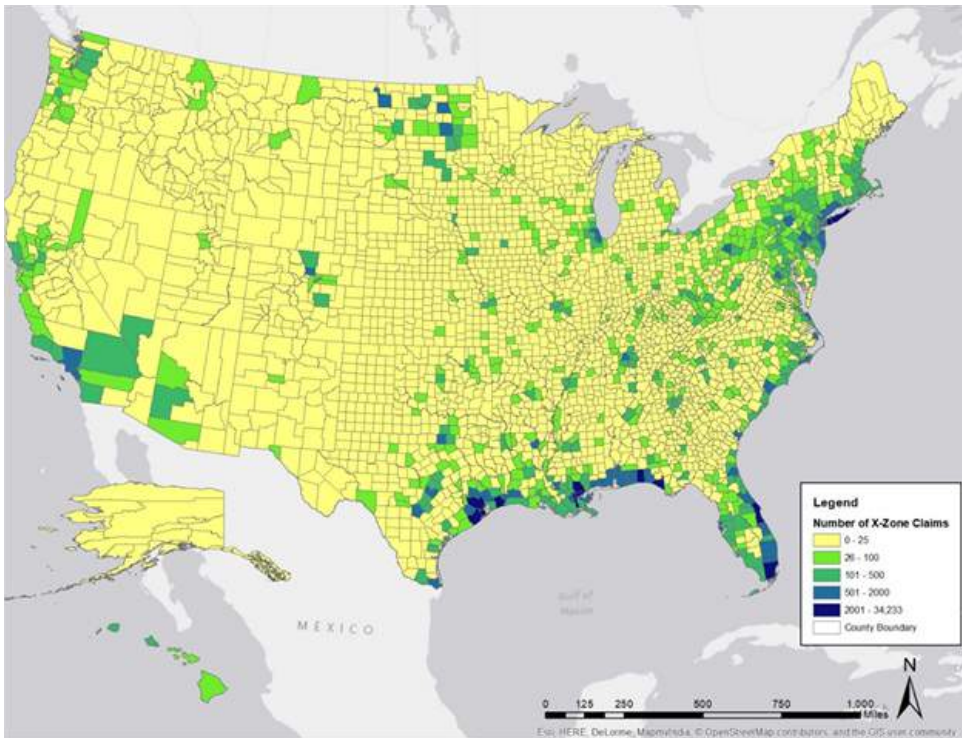


FIGURE 9. NFIP CLAIMS PAYOUTS BY COUNTY, 1974-2014 FOR PROPERTIES OUTSIDE THE SFHA (100-YEAR FLOODPLAIN). SOURCE: FEMA NFIP; MAP BY CENTER FOR TEXAS BEACHES AND SHORES, TEXAS A&M (CTBS), 2018.



Nationwide, approximately 25% of all NFIP claims are submitted by policyholders whose property is outside of the FEMA-defined 100-year flood zone. The percentage of these claims that are attributable to riverine and coastal flooding versus urban flooding is difficult to determine accurately. When claims are attributed in the FEMA data to a specific flood event, it is likely that claims in and outside the 100-year zone can be attributed to a riverine or coastal flood. Where flood claims are isolated in areas outside of the 100-year zone, it can be assumed that they are urban rainfall events rather than coastal or riverine. In both cases, determination requires careful analyses of the data at property level. Overall, trends in urban flooding are identified with the entire dataset; further analysis focuses on inferring flood damage outside the 100-year floodplain as well as storm surge zones to focus on urban flooding that is considered lower probability. Data used in this section include damages from 1972-2014.

Figure 9 indicates the number and location of claims against the NFIP from property located outside of the 100-year floodplain. While coastal areas are well known for their vulnerability to hurricanes and riverine flooding, and the threat of these events increases participation in the NFIP, the high participation outside of the 100-year floodplain in inland areas may reflect increasing attention to rainfall events versus riverine floods.

FLOOD INSURANCE

The NFIP was established by Congress under the National Flood Insurance Program Act of 1968 to enable homeowners in floodplains to obtain insurance at a time when commercial insurers were not willing to underwrite flood risks. Under the NFIP, insurance is made available to all homeowners and small businesses in and outside the Special Flood Hazard Area (SFHA) and located in communities that have agreed to be part of the NFIP. Lending institutions that offer federally-backed mortgages must require those owning structures located within the SFHA to purchase flood insurance (the requirement is on the lending institutions and not on the home/business owner). Premiums on properties located in the SFHA are considerably higher than those outside the SFHA. The existence of the mandatory purchase requirement leads home and business owners located outside the SFHA to the erroneous conclusion that if they are not required to purchase insurance, they do not have a risk.

This pattern is especially true in urban zones with a history of flooding related to significant rainfall events and not coastal or riverine floods. In 65% of the 242 responses concerning moderate or larger urban floods, 10% or less of residences damaged responded as being covered by insurance under the NFIP; in only 13% of the responses was the coverage greater than 50%. Since property owners may also purchase commercial flood insurance or add homeowner policies that cover basement or other flooding, survey respondents were asked to estimate extended coverage. In 80% of the 198 responses covering those affected by a moderate or larger urban flood, 10% or less of properties were estimated to have commercial coverage. In only 19% of the communities was the coverage greater than 50% (since data on personal insurance coverage is not public, it is difficult to obtain an accurate picture). In areas immediately adjacent to SFHAs where there has been flooding, data indicates that there is some adoption of NFIP insurance because the potential of a flood crossing the 100-year line is more obvious; however, the farther property is from a major river or stream, the less likely will there be the purchase of insurance.

Commercial insurance is also available in many areas and is frequently used to supplement NFIP insurance when a property's value exceeds the NFIP limit of $250,000 for residential structures.

Figure 10 indicates the percentage of NFIP flood claims outside of the SFHA by county as a percentage of the total claims in and out of the SFHA. Where the percentages are higher than 25%, it is more likely that urban flooding is also higher. It is apparent that when this figure is compared to Figure 9, the distribution of high claims areas is much different. In Figure 9, areas of high claims were clustered around traditional centers of hurricane and riverine flooding activity.

Insights can also be gained by mapping the property locations of FEMA Individual Assistance (IA) grants (Figure 11) to identify regions where individual assistance plays an important part in addressing post-disaster mitigation needs of communities; it can also indicate areas where the population may not have participated in or have access to the NFIP. Again, because of privacy act restrictions, geospatial accuracy is limited by zip code data.

At the local level, NFIP claims or other requests for assistance can be plotted against the 100- and 500-year flood zones to determine if the damages were occurring in areas where there were also NFIP claims (which include information on the cause of the flooding) or in areas where riverine flooding was not noted as a cause, leading one to assume urban flooding. Unfortunately, much of this information is covered by the privacy act, which limits its availability for analysis at the property level and pushes the analysis to broader areas such as the zip code or census tract, thereby reducing its accuracy.

Similar analyses could be used to examine data on buyouts, hazard mitigation grant program activities, public assistance grants, and commercial insurance payments.

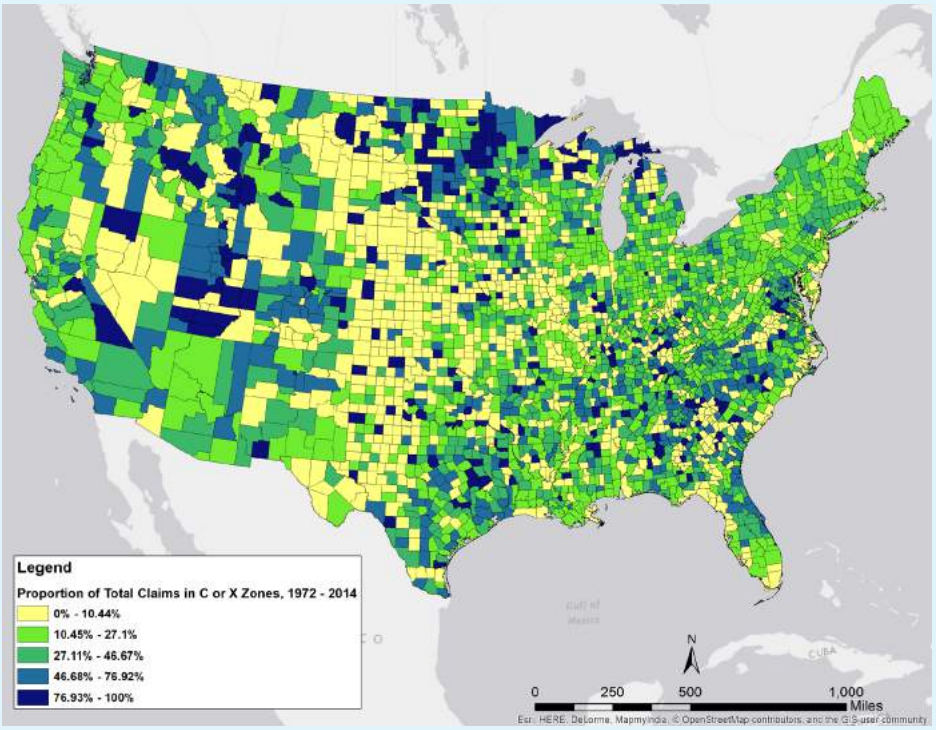


FIGURE 10. PERCENTAGE OF TOTAL NFIP CLAIMS BY COUNTY (1972-2014) ATTRIBUTABLE TO PROPERTIES OUTSIDE THE SFHA. SOURCE: FEMA NFIP; MAP BY CENTER FOR TEXAS BEACHES AND SHORES, TEXAS A&M (CTBS), 2018.

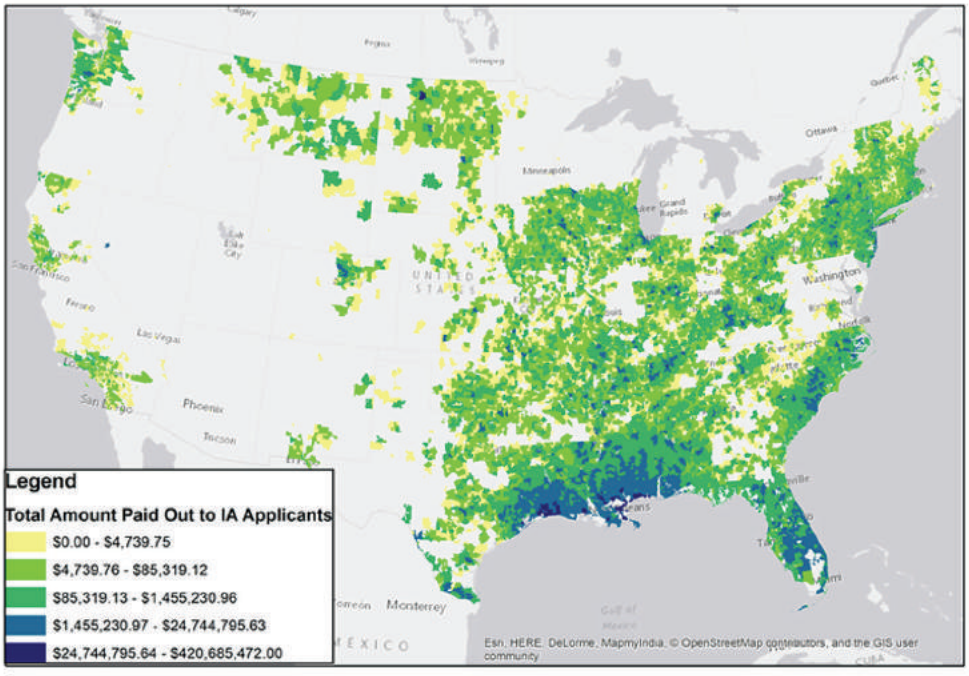


FIGURE 11. FEMA IA GRANTS BY ZIP CODE, 2004-2016. SOURCE: FEMA NFIP; MAP BY CENTER FOR TEXAS BEACHES AND SHORES, TEXAS A&M (CTBS), 2018.

ANALYSIS AT THE LOCAL LEVEL

Figure 12 indicates NFIP and commercial flood claims in Rock Island County, Illinois by census tract between 2007 and 2014. During that time, there were 1,972 urban flood damage claims. Seventy-one percent of these occurred outside the 100-year floodplain. Differentiating between riverine and urban flooding would require property-level analysis.[10]

Additional insight can be gained by plotting and then visually comparing different claims data sets to identify areas where NFIP claims are low and individual assistance requests are high, possibly indicating urban flooding as opposed to coastal flooding. In the case of Figures 13 and 14, by examining the New York, New Jersey, and Connecticut data at the zip code level, it is possible to identify specific neighborhoods where anomalies exist. Note the areas in New York City identified by the red oval.

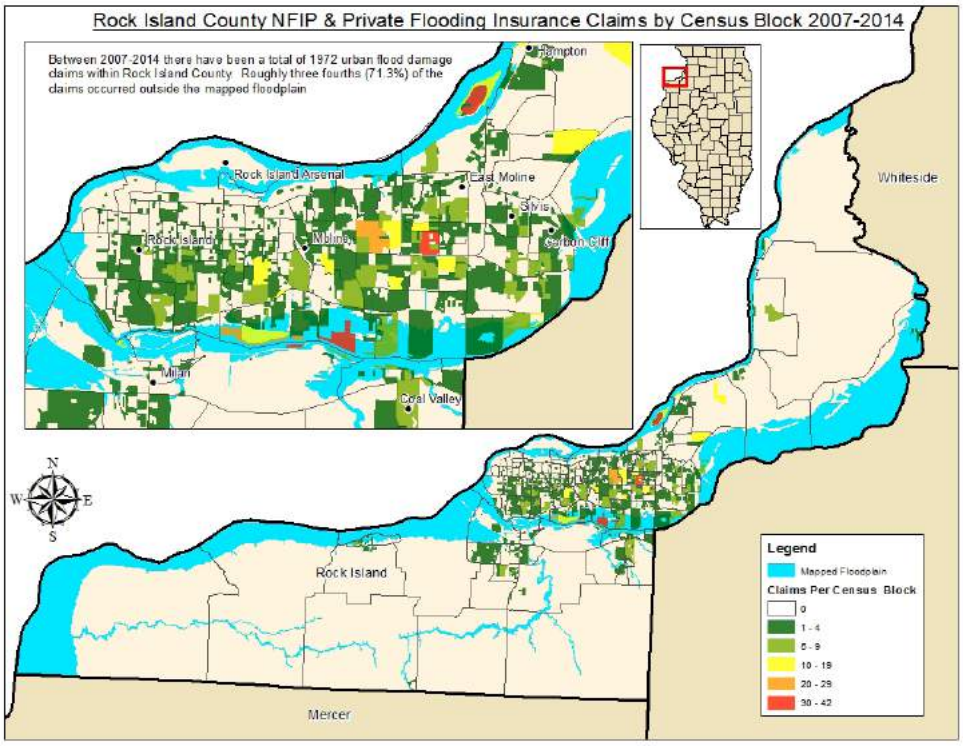


FIGURE 12. ROCK ISLAND COUNTY NFIP AND PRIVATE INSURANCE CLAIMS BY CENSUS BLOCK, 2007-2014. SOURCE: ILLINOIS STATE WATER SURVEY.

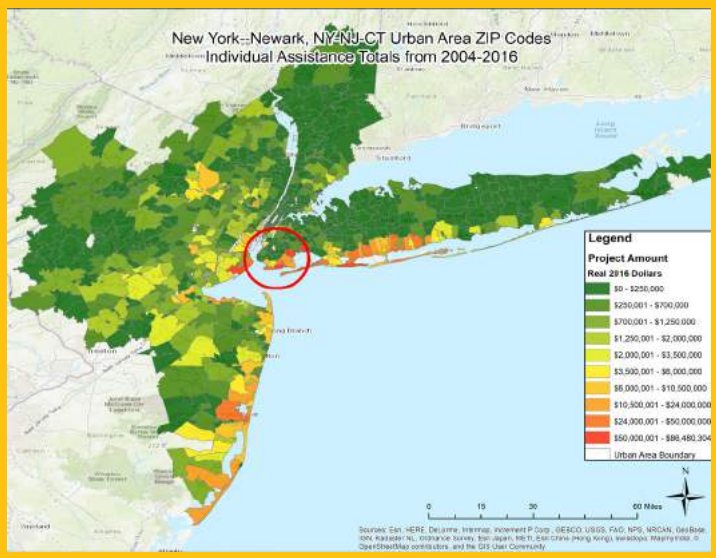


FIGURE 13. IA PROGRAM TOTALS BY ZIP CODE 2004-2016. SOURCE: FEMA NFIP; MAP BY CENTER FOR TEXAS BEACHES AND SHORES, TEXAS A&M (CTBS), 2018.

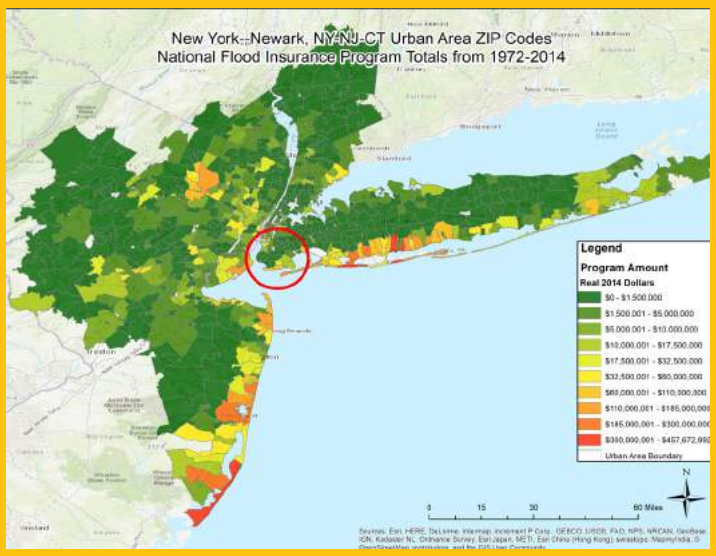


FIGURE 14. NFIP TOTALS BY ZIP CODE 1972-2014. SOURCE: FEMA NFIP; MAP BY CENTER FOR TEXAS BEACHES AND SHORES, TEXAS A&M (CTBS), 2018.

OTHER DATA SOURCES

Some communities, as resources permit, attempt to map and gather information on events as they occur. Such analyses generally represent points in time as opposed to collections that represent the true history of flood activity. Nevertheless, they do provide indicators of where flooding is occurring in a given community and offer initial notice to those in the community of where such risks exist.

Figure 15 was prepared by the District of Columbia government and regional agencies to identify areas prone to flooding. Except for flooding directly adjacent to the Potomac and Anacostia Rivers and Rock Creek, the majority of inundation within the District is caused by intense rainfall events coupled with poor drainage.

Interior Flooding in Washington, DC

The DC Silver Jackets produced this map from an accumulation of data from four sources: DC Water, the District Department of Transportation (DDOT), the Washington Metropolitan Area Transit Authority (WMATA), and the National Flood Insurance Program (NFIP). The map depicts areas where interior flooding occurs within Washington, DC's boundaries, and does not reference the 100-year or 500-year floodplains. This is not a regulatory map. Please see the associated report for more information on the data sources and how this map was created.

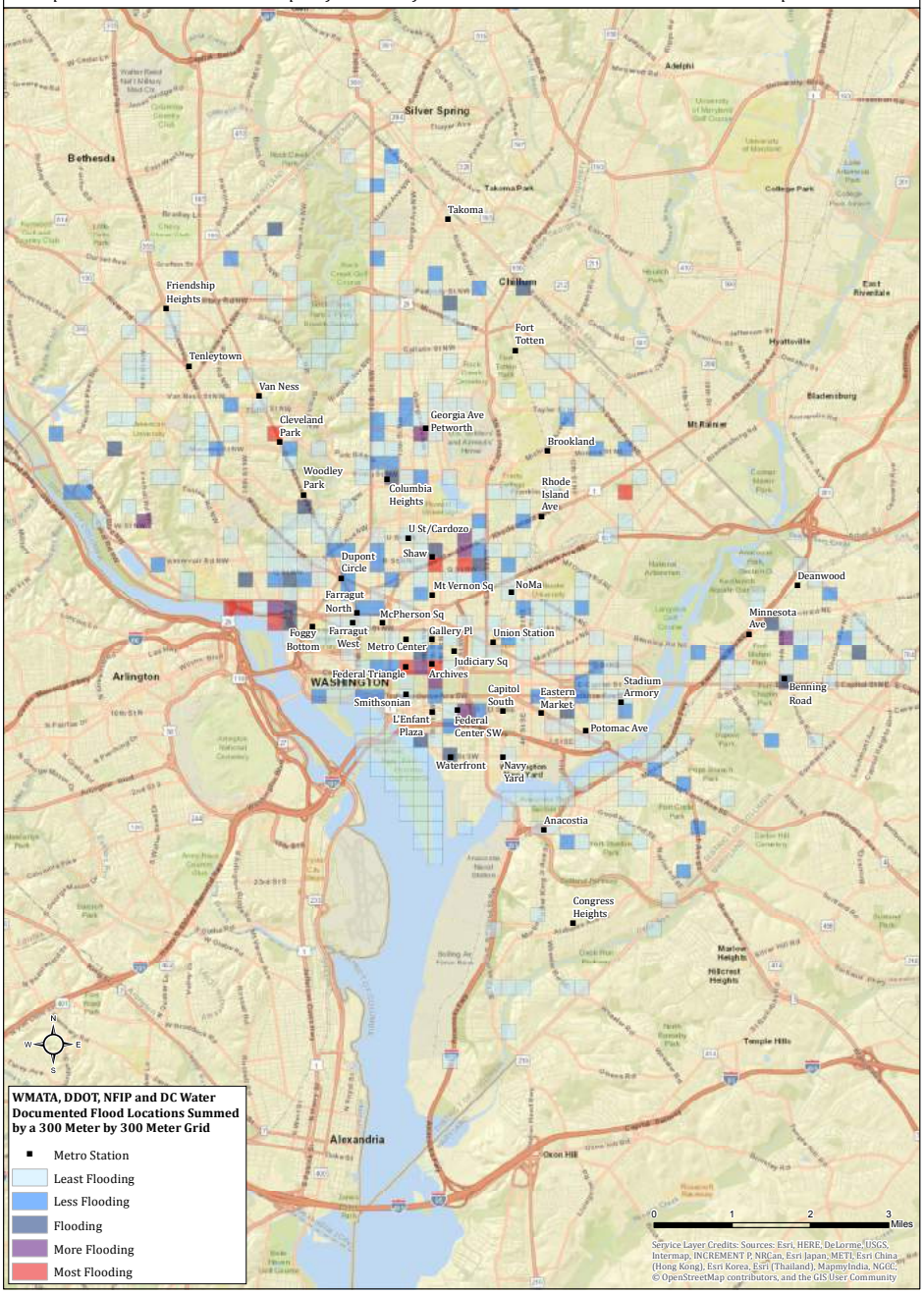


Figure 16a indicates the location of significant rainfall events reported by NOAA in the Baltimore, Maryland area that have produced urban flooding. Note the scatter within the region. The city of Baltimore developed a similar map to identify areas subject to frequent flooding (Figure 16b). Some of these areas are isolated and clearly represent urban flooding. Flooding in other areas adjacent to major streams or the harbor is caused by riverine and coastal events.

Following Hurricane Harvey, The Harris County Flood Control District in Houston identified houses within the country that flooded. Figure 17 plots the location of flooded homes and indicates that 68% of them were outside of the 100-year riverine floodplain. While some of this flooding is the result of stream and bayou flooding, much was related to heavy rainfall.

In conducting an engineering analysis of flooding in several neighborhoods in the Borough of Queens, New York City officials used contemporary engineering models to identify the impacts of major storm events. Figure 18 illustrates the result of a 100-year rainfall event on a neighborhood and identifies the urban flooding that occurs from poor stormwater drainage.

Nationally, 85% of study survey respondents (n=296) reported that some or all of the urban flooding was occurring outside the 100-year floodplain. They also indicated that urban flooding was typically scattered throughout their community as opposed to being focused in one area.

The state of Illinois study found that 90% of the claims for flood damage in urban areas that were filed between 2007 and 2014 were for properties located outside of the 100-year floodplain and most likely represented urban flooding.[11]

FIGURE 15. FLOOD-PRONE AREAS IN WASHINGTON, D.C. SOURCE: DC SILVER JACKETS, SILVERJACKETS.NFRMP.US/STATE-TEAMS/WASHINGTON-DC.

FIGURE 16A AND B. FLOOD-PRONE AREAS IN BALTIMORE, MARYLAND. LEFT MAP (A) SHOWS HEAVY RAINFALL EVENTS REPORTED BY NOAA. RIGHT MAP (B) INDICATES, IN PURPLE, FLOOD-PRONE AREAS. SOURCES: NOAA; MAP BY CENTER FOR DISASTER RESILIENCE; NOAA; MAP BY CITY OF BALTIMORE, 2017.

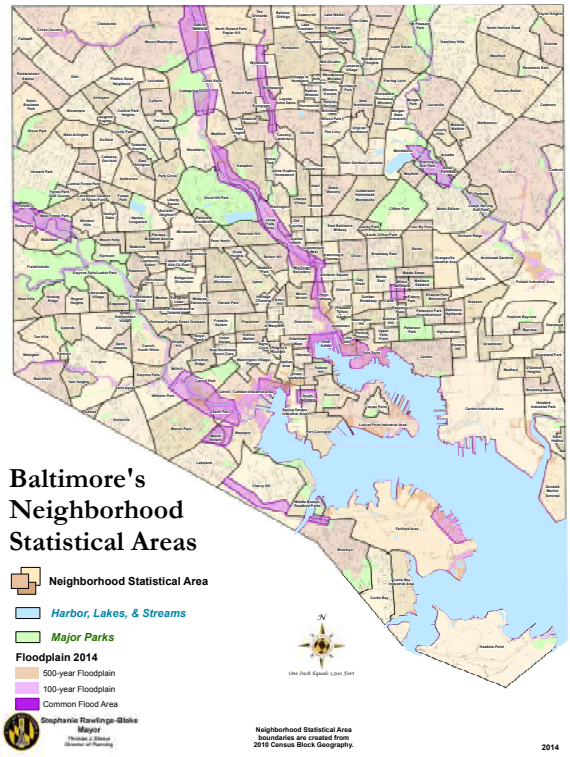
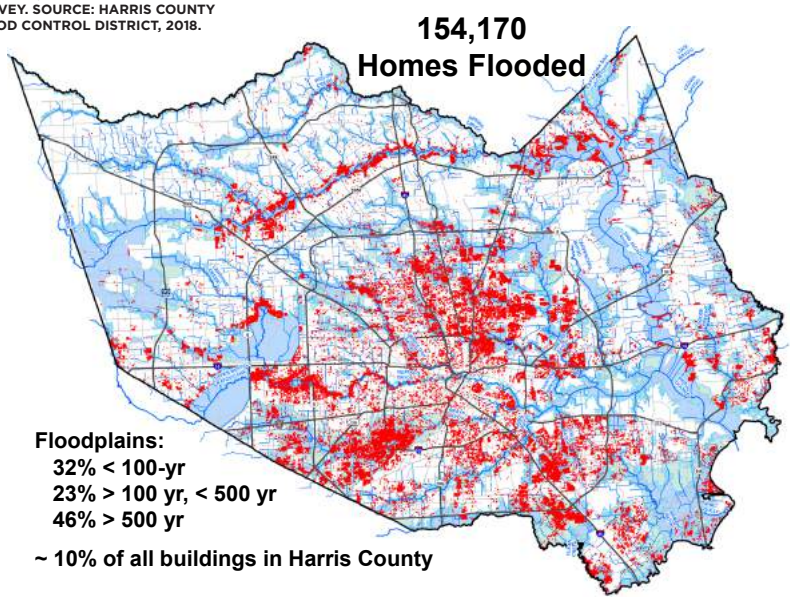


FIGURE 17. HOMES FLOODED IN HOUSTON, TEXAS DURING HURRICANE HARVEY. SOURCE: HARRIS COUNTY FLOOD CONTROL DISTRICT, 2018.



Observation:

Urban flooding is occurring in all regions of the United States. The exact locations of this flooding are difficult to determine accurately but is known to those in the communities responsible for flood and stormwater management.

FROM THE COMMUNITY

"The problem in most communities is lack of enforcement. Communities need a comprehensive plan to address development, infrastructure needs, stormwater runoff, and building codes. When a community doesn't address these issues it only exacerbates other problems and continued urban sprawl eats up rural areas causing flooding, erosion, and infrastructure malfunction. Only 1/3 of the state has building codes which enforcement is not uniform and the other 2/3 do not enforce floodplain regulations or even bother to look at stormwater."

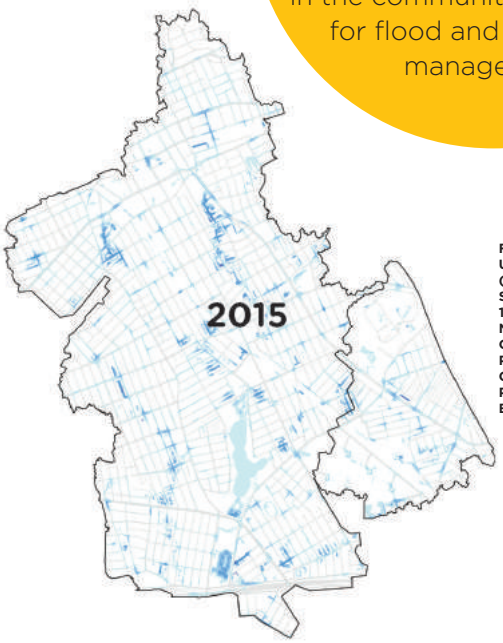


FIGURE 18. NEW YORK CITY: URBAN AREAS IDENTIFIED (LIGHT BLUE SHADING) AS SUBJECT TO FLOODING IN A 100-YEAR STORM. SOURCE: NEW YORK CITY DEPARTMENT OF ENVIRONMENTAL PROTECTION, JANUARY, 2017. CLOUDBURST RESILIENCY PLANNING STUDY. PREPARED BY RAMBOLL A/S.

IV. WHY DOES URBAN FLOODING HAPPEN?

While urban flooding is caused by a variety of factors, it essentially represents an inability on the part of a community to manage runoff from large rainfall events and to move the water off affected areas in a timely and efficient manner. Tackling this challenge requires a comprehensive approach to stormwater management that can identify the nature of the risk and that can build and maintain infrastructure that can deal with runoff.

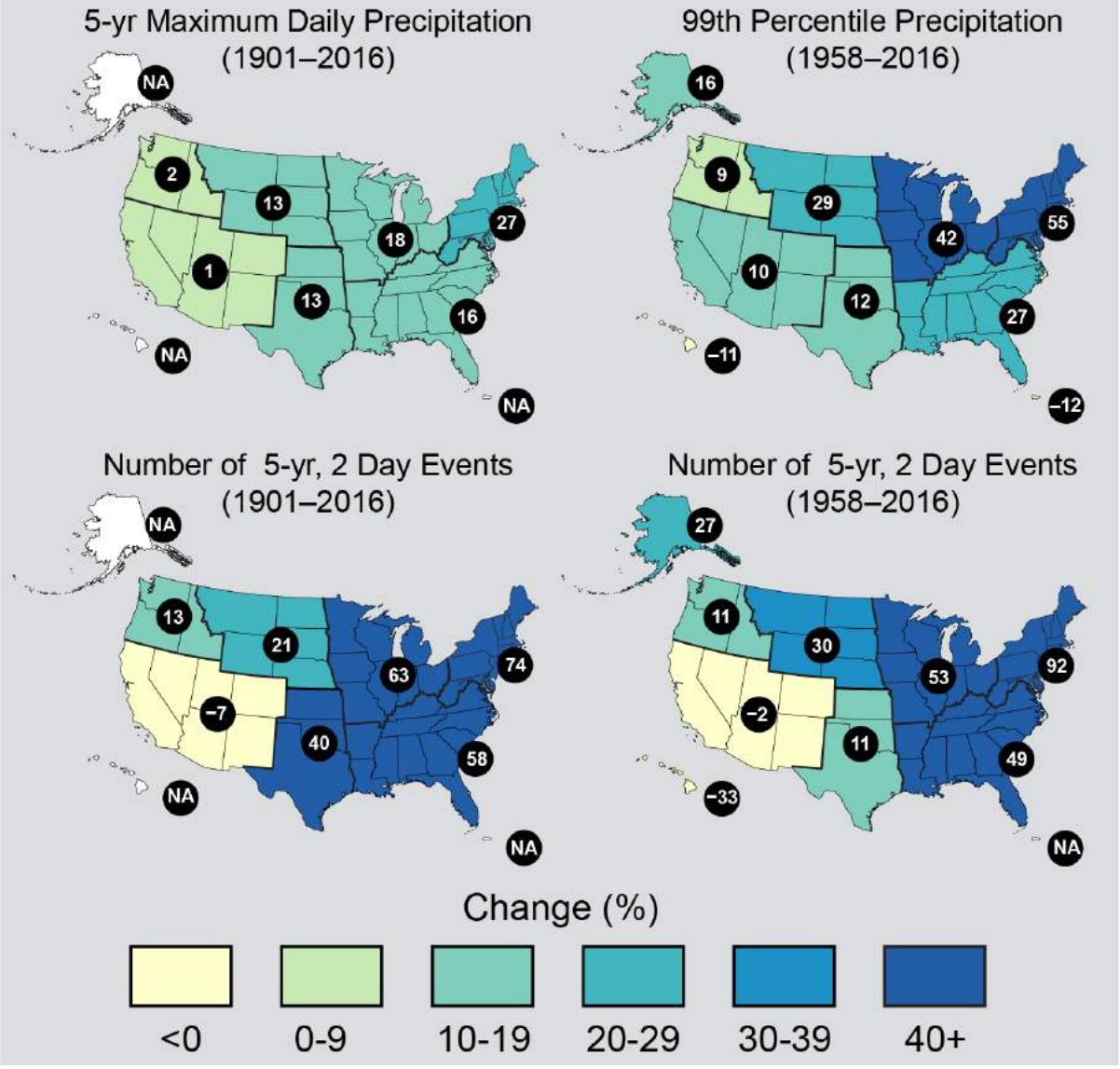


FIGURE 19. INCREASE IN EXTREME PRECIPITATION ACROSS THE UNITED STATES. "THESE MAPS...[INDICATE] THE PERCENTAGE CHANGE... (UPPER LEFT) THE MAXIMUM DAILY PRECIPITATION IN CONSECUTIVE 5-YEAR PERIODS; (UPPER RIGHT) THE AMOUNT OF PRECIPITATION FALLING IN DAILY EVENTS THAT EXCEED THE 99TH PERCENTILE OF ALL NON-ZERO PRECIPITATION DAYS...; (LOWER LEFT) THE NUMBER OF 2-DAY EVENTS WITH A PRECIPITATION TOTAL EXCEEDING THE LARGEST 2-DAY AMOUNT THAT IS EXPECTED TO OCCUR, ON AVERAGE, ONLY ONCE EVERY 5 YEARS...; AND (LOWER RIGHT) THE NUMBER OF 2-DAY EVENTS WITH A PRECIPITATION TOTAL EXCEEDING THE LARGEST 2-DAY AMOUNT THAT IS EXPECTED TO OCCUR, ON AVERAGE, ONLY ONCE EVERY 5 YEARS, AS CALCULATED OVER 1958–2016.... THE NUMBER IN EACH BLACK CIRCLE IS THE PERCENT CHANGE OVER THE ENTIRE PERIOD, EITHER 1901–2016 OR 1958–2016." SOURCE: CLIMATE SCIENCE SPECIAL REPORT, FROM EASTERLING ET AL. (2017).

FIGURE 20. LARGE HOMES REPLACE SMALLER HOMES, INCREASING RUNOFF FROM ROOFS AND DRIVEWAYS (HOUSTON). SOURCE: GOOGLE EARTH.

AGING AND INADEQUATE DRAINAGE SYSTEMS

Many older communities still rely on stormwater, water supply, and wastewater systems that were designed for conditions that existed decades ago and comprise infrastructure that has significantly deteriorated or is undersized for contemporary standards. **In the study survey, 70% of respondents (n=243) reported that inadequate drainage systems were their community's principal problem.**

INCREASES IN LOCAL AND REGIONAL RUNOFF

Of the 243 survey respondents, 57% noted that the failure to make infrastructure improvements as changes occurred in hydrology (increased rainfall) and developments (paving land over), increased runoff within the communities. For example, Midwestern states have experienced a 31% increase in very heavy precipitation events between 1958 and 2007, and this trend is expected to continue.[12] The 2017 National Climate Assessment indicates that "heavy downpours are increasing nationally, especially over the last three to five decades. The largest increases are in the Midwest and Northeast. Increases in the frequency and intensity of extreme precipitation events are projected for all U.S. regions" (Figure 19).

When large new developments are constructed, they often replace forests and fields that previously captured rainfall or slowed stormwater migration. New homes, streets, and driveways move rainfall quickly into natural and constructed drainage systems, frequently overwhelming their capacity and creating flood problems. This is also an issue when smaller houses are replaced by larger structures (aka, "McMansions"); natural absorption is lost and runoff is increased, frequently overwhelming the existing drainage systems (Figure 20). Large-scale, upstream development can significantly alter the flood risk to downstream communities that must accept the increased water flow.

FROM THE COMMUNITY

"The most significant and constant & unaddressed cause of flooding in Overland Flow caused by insufficient attention to lot design local drainage at the subdivision block and lot level slab-on-grade construction, especially when on-site drainage impacts more than 2 lots before it reaches public conveyance, such as public streets and storm sewers."

FIGURE 21. TYPICAL URBAN STREET FLOODING. SOURCE: S.D. BRODY, TEXAS A&M.

FIGURE 22. A BLOCKED CATCH BASIN IN DETROIT, AS REPORTED BY A HOMEOWNER. SOURCE: EN.SEECLICKFIX.COM.

SEWAGE AND STORMWATER BACKUPS

In many cases, the absence of building standards or adequate design at the time of initial construction has led to systems that are unable to handle the impact of community growth, resulting in sewage backups on a large scale. In many communities, there is a need to separate stormwater and wastewater disposal to prevent pollution, but funds are not available to carry out such a retrofit activity. Modern technology has developed valves or similar systems that can prevent many, if not all, backups into homes, but their expense and installation requirements are outside the means of low-income residents in high-risk zones.

CHANGES IN LOCAL PHYSICAL CONDITIONS

In some cases, changes in groundwater conditions or a failure to even consider groundwater as a threat only increase the challenges for local officials. Highway and road construction often create obstructions that block historic drainage paths. Some communities' original drainage plans called for the use of streets as rainfall storage areas, but the increase in runoff and rainfall now frequently exceeds the street storage capacity and pushes water into homes and businesses. The use of streets for storage also creates severe transportation problems and interferes with commuting and school transportation. During excessive rainfall periods when street storage is frequently ineffective, the overflow creates new and unforeseen pathways for drainage flows with unexpected, negative consequences; in recent rainfall events, sound barriers along highways have created "dams," flooding properties behind them.

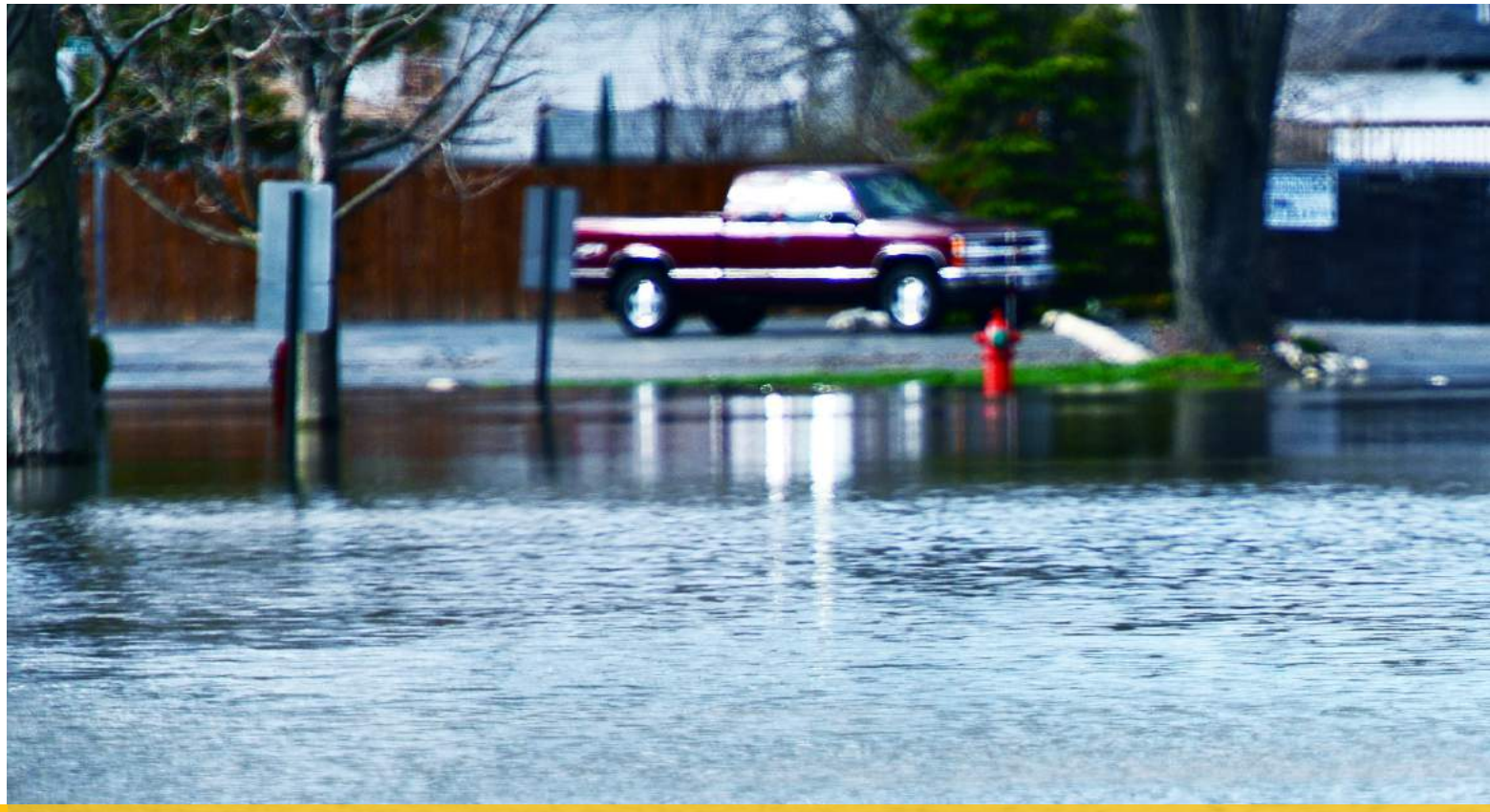
FIGURE 23. A BLOCKED STREET DRAIN HOUSTON. SOURCE: S.D. BRODY, TEXAS A&M.

FAILURE TO MAINTAIN DRAINAGE SYSTEMS

All stormwater collection systems require continuous maintenance. Drain blockage, the collapse of pipes, or restrictions in channel capacity, retention, and detention storage can substantially reduce the function of a stormwater system and create flooding in the affected areas. For example, because of a lack of funding, the city of Detroit has been unable to routinely clean its 95,000 catch basins since 2010; where basins are blocked, streets flood. This year, with an infusion of resources, it will begin a three-year program to inspect and clear 30,000 of these catch basins.[13] The city reports that 75% of the drains citywide are covered by debris or have a blockage. While Detroit's problems are severe, they are mirrored on a lesser scale by similar problems in other communities (Figures 22, 23).

In many communities, areas prone to river, stream, or coastal flooding are protected in part by the construction of levees and floodwalls, which block the rising waters from entering low areas. However, when heavy rainfall events occur either in conjunction with external flooding or independently of it, the interior areas must address disposal of the rainwaters that are accumulating behind the structures. When the water elevation on the river side is higher than the elevation of rainwaters on the inside, and gravity evacuation cannot occur, pumps must be used. When they fail from lack of maintenance or power failures, the results can be disastrous. In August 2017, three years after completion of the $14 billion post-Katrina upgrade of the New Orleans levees, several generators powering pump systems designed to evacuate water from inside the levees during heavy rainfall events failed and caused considerable damage.[14]

HOUSTON, TEXAS, PHOTO BY G. GALLOWAY



V. THE CONSEQUENCES OF

Of the 325 survey respondents reporting urban flooding impacts, 50% reported that the consequences of flooding were moderate or significant; 2% reported disastrous consequences. In Canada, severe rainfall has replaced fire as the leading cause of damage to homes. The cost of sewer backup and basement flooding exceeds $2 billion (CND) per year and has "been rising at an unsustainable rate for more than 25 years."[15] Information drawn from interviews conducted by the study team support this general impression. In the case of major rainfall events in large metropolitan areas such as Detroit, Washington, D.C., and Baton Rouge, the consequences are often disastrous; because of their magnitude, these events are chronicled by federal, state, and local agencies. In contrast, when a three-block area in a city is frequently flooded by heavy rainfall trapped in depressions, the flood event is noted, but the damage rarely becomes part of the permanent record. When heavy rains fill streets with water and damage cars parked in these locations, some owners make individual insurance claims; yet in many cases, owners lack coverage for flood-related damages to their automobiles. In general, the consequences of urban flooding fall into two categories: economic and social.

THE ECONOMIC COSTS OF URBAN FLOODING

At the national level, no one federal agency is charged with responsibility for identifying and accumulating data about flood losses. Any tally of urban flood losses, where it exists, is far less accurate than the riverine and coastal data.

Each agency manages its own programs and the expenditures that support them. FEMA manages the NFIP and maintains data on claims paid and grants supported. NFIP policy payments generally reflect losses, but individual assistance payments, which are capped, generally only report part of the loss; homeowners must deal with costs above the cap on their own. Public assistance payments reflect losses, but only to the level of funds available (not actual losses). HUD tracks its grants, as does the Small Business Administration (SBA), yet its loans represent federal support rather than the actual amount of damage incurred. Commercial insurers track loss data through their policies and release most of it to the public at the macro level. When seeking support for a Presidential Disaster Declaration, states are required to identify the losses that qualify them for federal aid. Typically, however, once the declaration has been made, concern over the completeness of loss of data disappears and further tabulations are left to academics and the media.

Observation:

There is no single federal agency charged with the responsibility of collecting and evaluating flood loss information. As a result, all national flood loss estimates are considered "approximations" according to NWS, and therefore are of marginal use in conducting accurate economic analyses to support urban flood risk reduction mitigation.

URBAN FLOODING

Over the years, NOAA has attempted to gather data on storm-related losses nationwide, but program modifications and a reduction in funding has resulted in a lack of data continuity. NOAA indicates that "the National Weather Service's primary mission is to provide weather information for the protection of life and property. Ancillary to this mission, NWS field offices provide loss estimates for significant flood events... Therefore, the resulting data are to be considered rough estimates, and may be unrepresentative of actual damages."[16]

Little effort has been made to separate losses resulting from riverine and coastal floods and losses from urban flooding. Since many losses from urban flooding are caused by storms with limited spatial extent, these losses seldom reach the level necessary to obtain a Presidential Disaster Declaration, and the incentive to track losses beyond that point is limited. As indicated in a previous section, however, NOAA has provided descriptive information about storm events since 1993, including damages reported by various sources in a storm area, so that estimates can be made of some of the losses attributed to urban flooding. Between 1993 and 2017, NOAA reported losses of over $17 million on 3,663 flood events, with 27 deaths attributed to those events. In some cases, although damages occurred, the NWS data collectors were unable to obtain them for the record.

Research conducted by Chicago's CNT in 2012 indicates that communities across the Great Lakes region are suffering from the impacts of urban flooding caused by moderate and heavy rain running off roofs, roads, and parking lots. The economic and social consequences can be considerable. Experts estimate that wet basements decrease property values by 10-25%, and that, according to FEMA, "almost 40% of small businesses never reopen their doors following a flooding disaster." Statistics from the SBA indicate that "over 90% of businesses fail within two years of being struck by a disaster." [19]

The costs of urban flooding are finally being recognized in both financial and social terms. Accurate records on urban flood losses are not well maintained or even captured. Little is done to capture secondary effects, such as loss of hourly wages for those unable to reach their workplaces; hours lost in traffic rerouting and traffic challenges; disruptions in local, regional, and national supply chains; or school closings with resultant impact on parents. Where all these costs come together, seemingly minor economic impacts of urban flooding would grow significantly.

THE SOCIAL IMPACTS OF URBAN FLOODING

Advocates for national fair and equitable housing have contended that low-income households are frequently—for economic and discriminatory reasons—forced to live in areas subject to higher flood risk. In the 291 reporting communities in the survey, 50% of those affected by urban flooding were residents with low and moderate-income status; an additional 20% were reported to be in the low-income group.[17]

In 2015, the NYU Furman Center reported that "while the nationwide poverty rate and the poverty rate of those living in the 100-year and combined 100- and 500-year floodplains are about the same, a higher share of the population lives in a moderate- or high-poverty census tract in the 100-year and combined floodplains than in a non-floodplain (Figure 24). [Study note: in many cases, those said to be living in a "non-floodplain" actually live in a natural floodplain or a topographic anomaly and are still subject to flooding.] While at the national level, the population in the floodplain largely mirrors the population more generally, the Furman Center notes that "disaggregating the data at the state level begins to reveal important variation and localities may see more variation as they explore neighborhoods within their jurisdiction."[18]

In April 2018, FEMA released a report on the affordability of flood insurance and provided data on the distribution by income of those purchasing insurance under the NFIP. The data indicated that low-income households are less likely to purchase flood insurance than higher-income households, even though low-income families are more likely to live in high-risk flood zones (low-income was defined as having less than 80% of the area median income). The data indicated that slightly more than 50% of households located in the 100-year floodplain (SFHA) that did not have insurance were low income. It also stated that of those households in the SFHA that had NFIP insurance, only 26% were low income. The Natural Resources Defense Council noted that median income of households without flood insurance was only $40,000, and, "with the average policy costing $1,098 per year, those that can least afford to pay for flood insurance are those who can least afford to be without, given a high level of risk." For example, in Louisiana, a high flood state, the median income of the 240,000 households lacking flood insurance and living in the SFHA was $33,000, while the median income of the 221,000 with flood insurance was $73,000 (Figure 25).

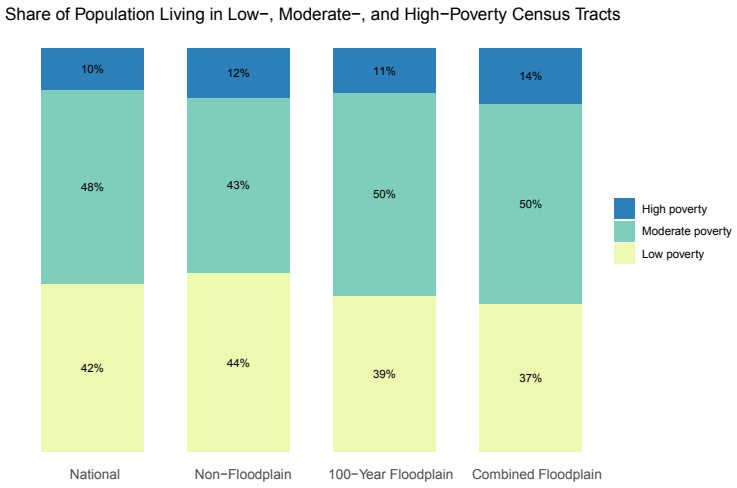


FIGURE 24. POPULATION IN U.S. FLOOD PLAINS. SOURCE: NYU FURMAN CENTER (DECEMBER 2017). DATA VIA AMERICAN COMMUNITY SURVEY (2011-2015) AND FEDERAL EMERGENCY MANAGEMENT AGENCY.

FROM THE COMMUNITY

"Urban flooding generally affects the poor at higher levels than more prosperous segments of our society. Additionally, the majority of public housing and poor neighborhoods developed 40 to 50 years ago, at a time when well-to-do urbanites traded townhomes for suburban life and that urban vacuum created low-cost opportunities for the bottom middle class to become first-time home owners. These traditionally high flood-prone areas evolved from middle class to low middle class to working poor neighborhoods and now they're in areas that are prime for commercial redevelopment as our urban centers continue to expand outward. It is time that we look at getting a do-over. An opportunity to re-imagine what public housing should look like, feel like, and be, instead of what we allowed it to become. We should find new areas that can be re-developed into mixed-use sporadic housing that doesn't create a conglomeration of the downtrodden but a comingling of our poor with middle class home owners that encourages opportunity and discourages blight."

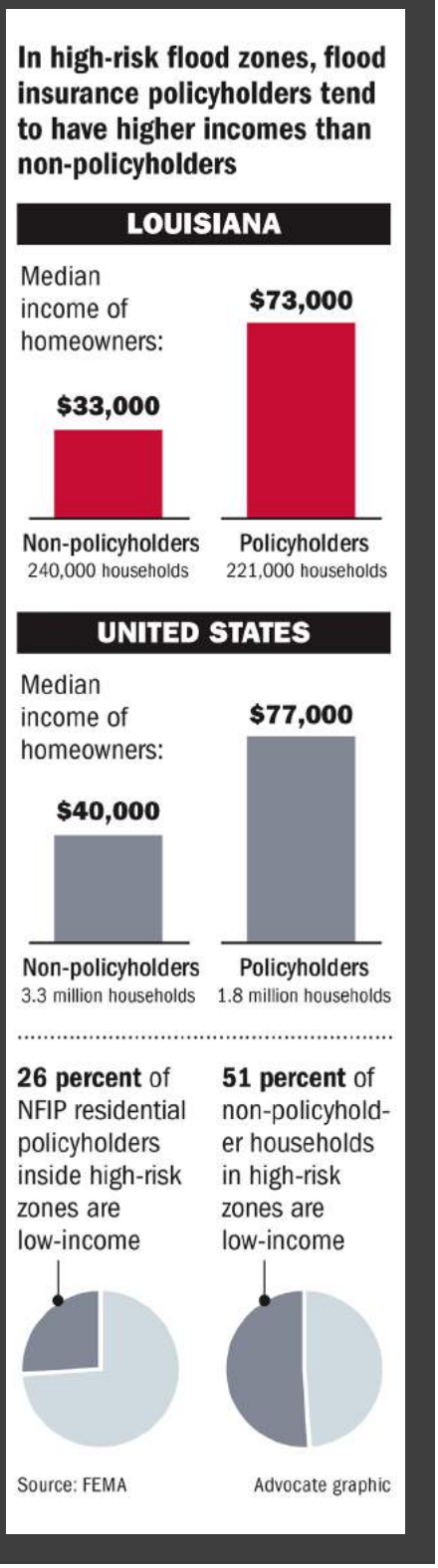


FIGURE 25. INCOMES OF FLOODPLAIN OCCUPANTS. SOURCE: DAN SWENSON/THE ADVOCATE, THEADVOCATE.COM.

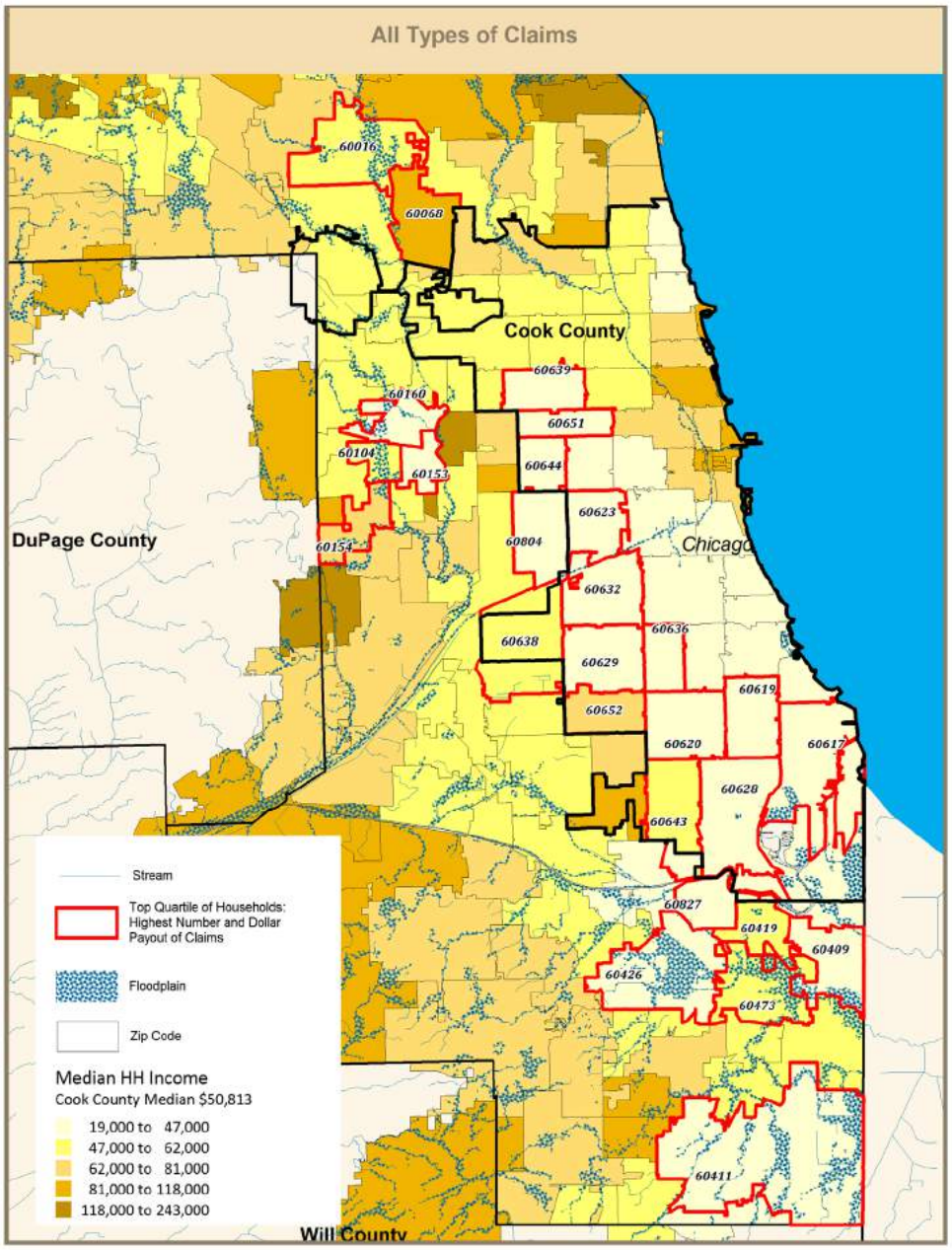
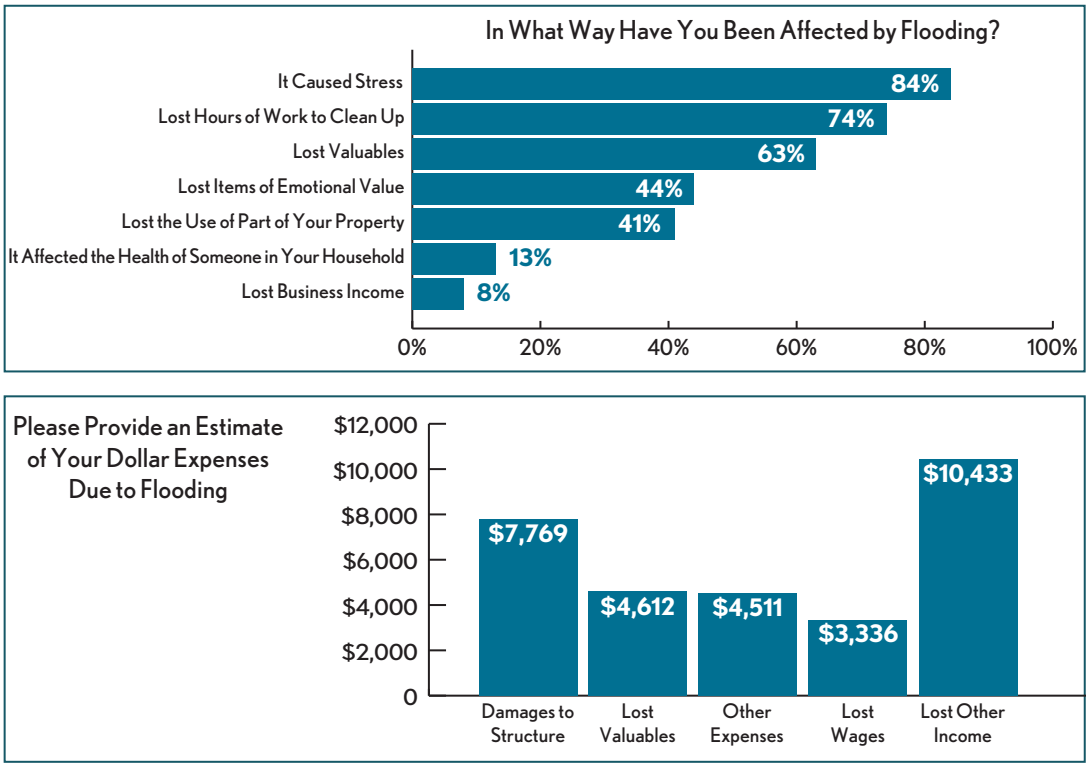


FIGURE 26. MEDIAN HOUSEHOLD INCOMES IN CHICAGO ZIP CODES WITH LARGEST TOTAL FLOOD CLAIM PAYOUTS AND NUMBERS, 2007-2011. SOURCE: CENTER FOR NEIGHBORHOOD TECHNOLOGY, THE PREVALENCE AND COST OF URBAN FLOODING, ©2014.

FIGURE 27. IMPACTS OF FLOODING IN CHICAGO ON FLOOD-AFFECTED POPULATION (N=115). SOURCE: CENTER FOR NEIGHBORHOOD TECHNOLOGY, THE PREVALENCE AND COST OF URBAN FLOODING, ©2014.

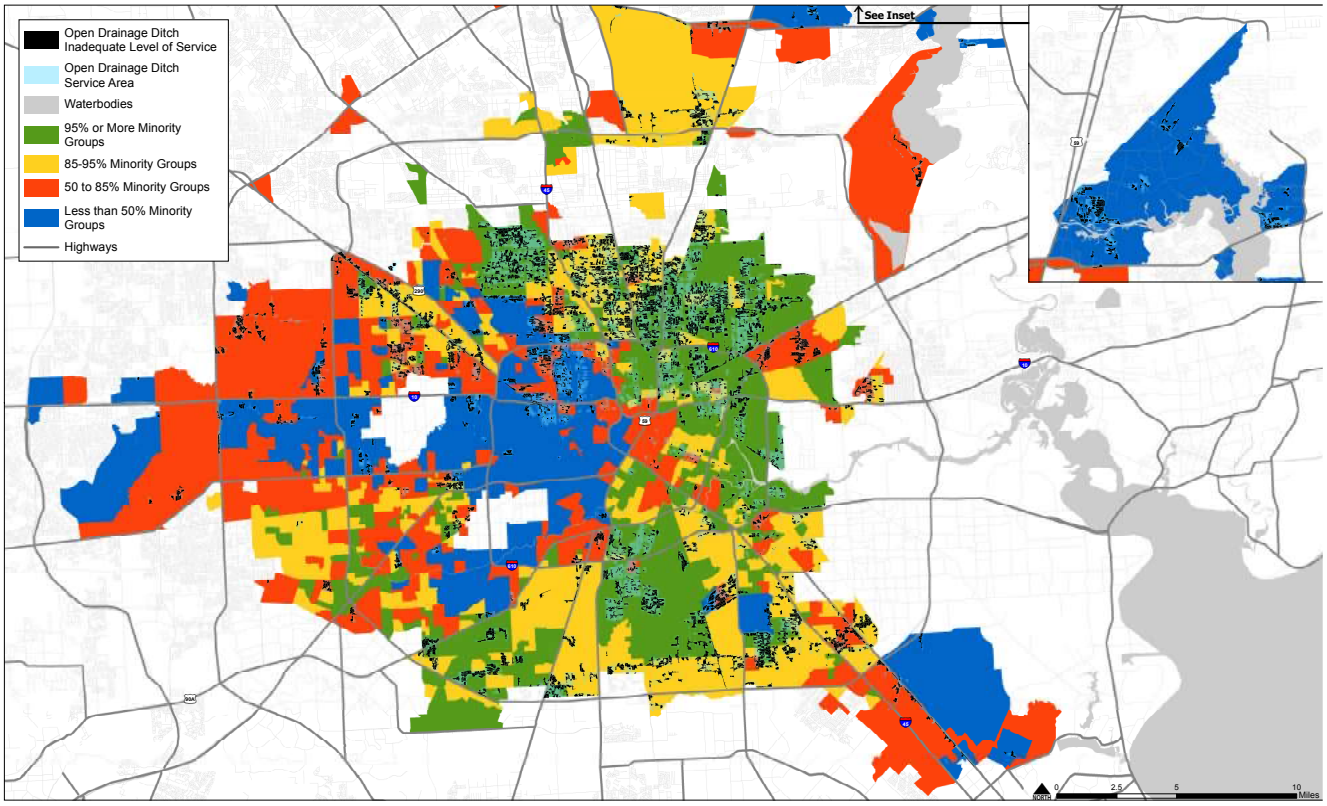


In Cook County, Illinois, analysis by CNT of flood claims over a five-year period indicated that the household incomes in 67% (18 of the 27) of zip codes with the highest concentration of flood damages were below the median for Cook County as a whole. Nine of the 22 zip codes in Cook County had no SFHA within the zip codes yet are in the zip codes with the highest concentration of damage claims, indicating damages were from urban flooding (Figure 26). [19]

Several flood studies have found that those with low or moderate income and those facing social challenges lack the resilience to deal with flooding of any kind, particularly repetitive urban flooding. For those lacking critical resources (savings, insurance, etc.), the flood losses gnaw away at their well-being. The CNT found that of those affected by urban flooding in a Chicago study, "84% suffered stress and 13% ill health. Forty-one percent lost the use of part of their property, 63% lost valuables, and 74% lost hours of work to clean up" (Figure 27). [20] Seventy percent of the respondents to this study's survey (n=227) indicated that rental properties represented 25% or less of properties moderately affected by urban flooding.

Problems created by living in a flood-prone area are compounded by the level of protection and mitigation provided to those that live in underserved communities. In 2014, the city of Houston, Texas commissioned a study on open ditch drainage, recognizing that this approach is generally not as effective as underground movement of stormwater. On completion of the study, an analysis by Texas Housers (the Texas Low Income Housing Information Service) found that 88% of Houston's open ditch drainage are in African American neighborhoods; according to the city's own report, nearly half of these ditches couldn't provide stormwater protection for the homes they serve in even modest storms (Figure 28).

GRAND RIDGE, FLORIDA, PHOTO BY ANDREA BOOHER/FEMA

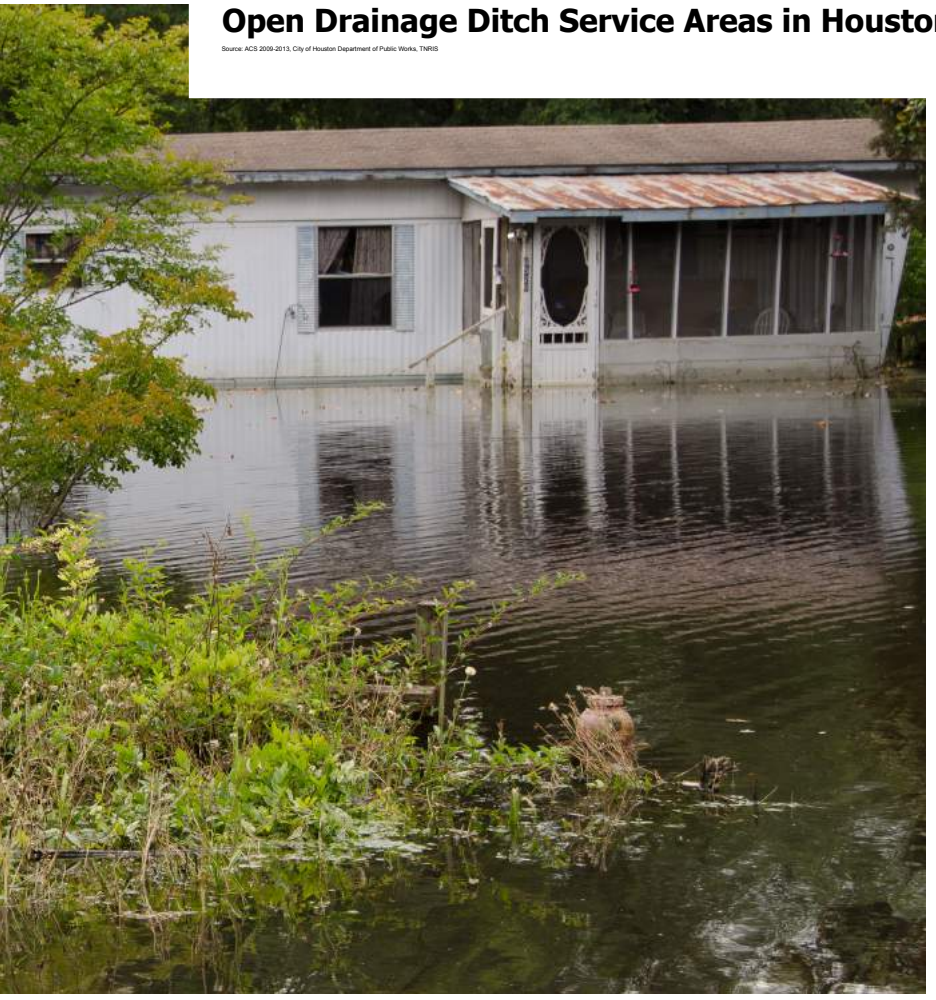


Open Drainage Ditch Service Areas in Houston, Texas

Source: ACS 2009-2013, City of Houston Department of Public Works, TNRIS

Texas Low Income Housing Information Service

FIGURE 28. OPEN DRAINAGE DITCH SERVICE AREAS IN HOUSTON, TEXAS. SOURCE: TEXAS LOW INCOME HOUSING INFORMATION SERVICE, 2017.



FROM THE COMMUNITY

"[Redacted] was developed and exists on [high ground]. The urban flooding that occurs in the heart of the central city is mainly attributed to existing drainage infrastructure that predates today's design standards or insufficient pipe sizes for the now fully developed urban areas. The [redacted] and [redacted] parts of the city have many socio-economically depressed areas. These areas were developed when building codes allowed dense neighborhoods to be constructed without adequate buffers in close proximity to streams. There have been little improvements due to lack of funding, State permit approval, and in some cases, will."

VI. WHAT CAN BE DONE ABOUT URBAN FLOODING?

After a natural disaster, the federal government supports recovery with a variety of programs designed to supplement state and local capabilities, particularly when the magnitude of disasters is so high that state and local governments cannot deal with them alone.

CLEARWATER, FLORIDA, PHOTO BY KATHY/CC BY 2.0

In 1936, the federal government, in collaboration with state and local governments, developed flood control works where such projects were justified. Through the construction of dams, levees, channels, and other works (primarily by USACE), major flood losses were reduced but not eliminated, and the growth in population continued to see people move to areas of flood risk. Between 1984 and 2009, USACE estimated that flood risk reduction projects prevented over $700 billion in damages.[21]

Through the 1968 NFIP, the federal government-initiated efforts to mitigate flood losses using a federally-backed framework that permits home and business owners to purchase insurance for properties susceptible to flooding when their communities agree to participate in the NFIP and limit future development in flood-prone areas. The magnitude of NFIP claims has served as a measure of the nation's flood vulnerability.

Between 1974 and 2014, the NFIP has paid out $51.6 billion dollars in claims (Figure 5). Claims paid out in 2015-2017 are estimated to be more than $13.4 billion, largely because of major hurricanes and storms along the Gulf Coast and in Puerto Rico. The majority of the claims payments are as a result of riverine, coastal, and major storm flooding.

As previously discussed, in addition to the NFIP, FEMA provides post-disaster assistance in the form of IA grants and grants to public entities (Public Assistance —PA) largely for infrastructure repair. The SBA is authorized to provide loans to individuals and businesses affected by flooding. The FEMA Hazard Mitigation Grant Program (HMGP) funds large hazard mitigation projects, including buyouts that occur in multiple counties or statewide. Unlike PA funds, which are intended to help communities quickly respond to and recover from disasters, HMGP funds are intended to support projects and measures that will help a community reduce its risk from future disasters.

Figure 29 represents the range of the extensive federal support for flood-related disasters in terms of total payout amounts from these programs to entities within each county across all the available years from each dataset, from 2004-2014. Greater amounts of damage along heavily populated coastal counties can be visualized. All states along the Gulf of Mexico reported higher amounts of loss due to their increased vulnerability from hurricanes, storm surge, and higher precipitation averages. Several Louisiana and Texas counties display higher than average losses, possibly due to their encounter with multiple tropical events, such as Hurricanes Allison, Katrina, and Ike. The second most noticeable location

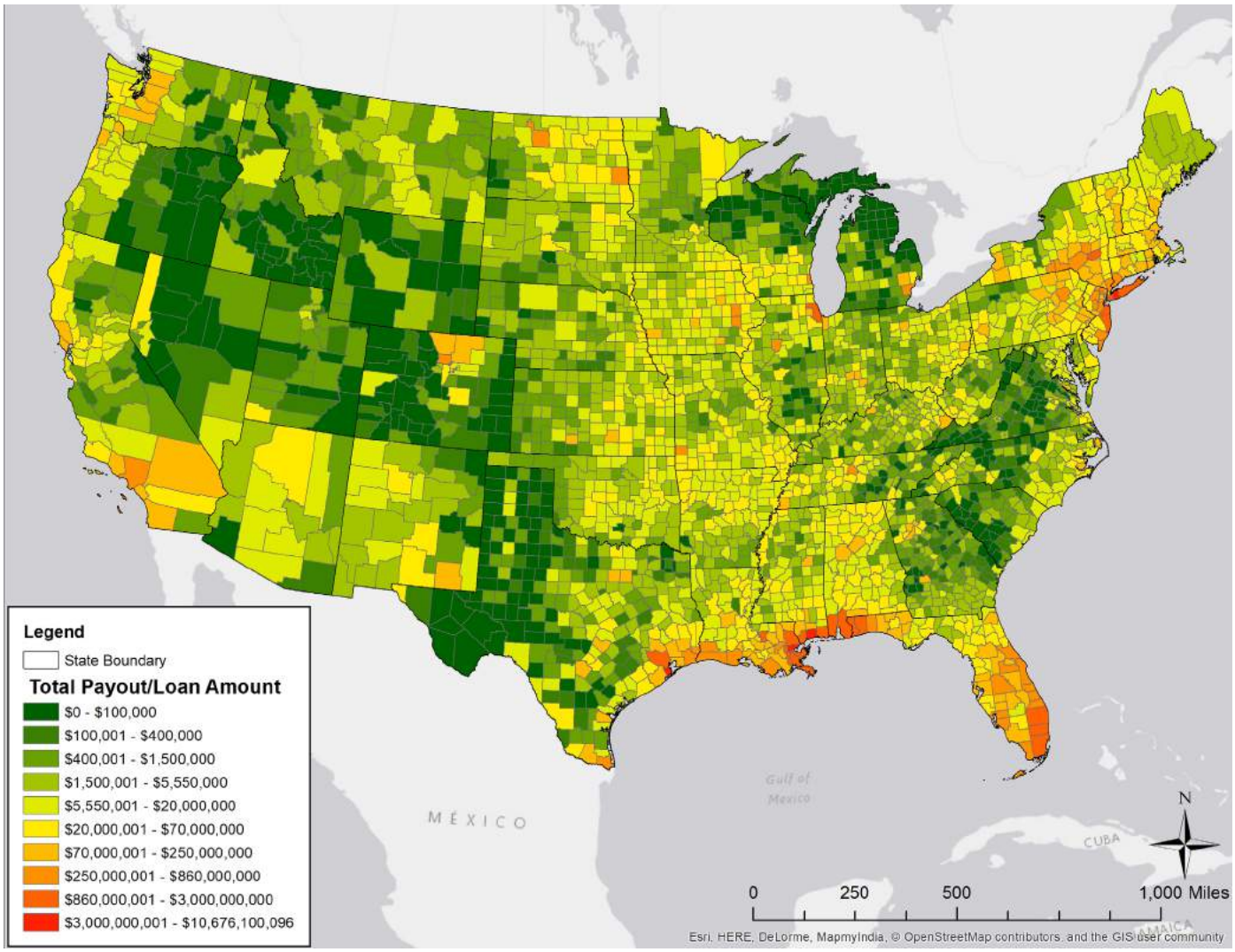


FIGURE 29. TOTAL FEDERAL PAYOUTS/LOAN AMOUNTS FROM NFIP, SBA, IA, PA, AND HMGP BY COUNTY 2004-2014 (ADJUSTED). SOURCE: FEMA NFIP, HUD, SBA; MAP BY CENTER FOR TEXAS BEACHES AND SHORES, TEXAS A&M (CTBS), 2018.

in the United States reporting higher amounts of loss is throughout the coastal and near-coastal areas of New York, New Jersey, and Connecticut.

Assessments at broad spatial scales are useful, but dealing with urban flooding requires attention to the differences that exist among local communities. Every community is different in its physical and social makeup and owns a unique history of development. Over the years, a community's physical attributes (topography, soil, flora, and fauna) have shaped its approach to dealing with stormwater and urban flooding. The economic strength of its population has determined how it addressed the problems it faced. Techniques used to mitigate urban flooding are many and are often seen in the quality of a community's infrastructure and its capability to deal with such challenges. Older communities, in part, must rely on stormwater systems that have been in place for decades or centuries. Standards initially established as reasonable are no longer seen as appropriate. Managing a 10-year storm, a high bar 50 years ago, may no longer be a viable standard for a growing community, but represents the capacity of many systems that are already in the ground.

Observation:

There are many strategies for tackling urban flooding, but in all cases, it is the combination of tool selection, funding, and a public's will to proceed that determine the level of success.

COMPREHENSIVE PLANNING

Serious efforts to reduce urban flooding require a forward-looking plan for the development, implementation, and enforcement of building codes through collaboration and coordination among neighboring governmental entities responsible for managing urban flooding and the development of comprehensive plans for the watershed.

Urbanization and the proliferation of impervious surfaces across watershed units are major contributors to adverse impacts associated with flood events. The conversion of natural landscapes to urban or suburban developments can diminish the functionality of hydrological systems, reducing soil infiltration and increasing surface runoff and peak discharge into nearby streams. Flood impacts are driven not solely by the amount of impervious surface, but by its pattern and intensity across a given landscape. The specific form of the built environment is the more important trigger for flood losses over time.

Large amounts of sparsely-developed areas consistent with "sprawl" actually exacerbate property damage from flooding. In this situation, outwardly expanding, low-density development patterns can fragment hydrological systems and amplify surface runoff by spreading out impervious surfaces over a larger area. Features of the built environment, such as sound walls, roadways, fences, etc. can exacerbate urban flooding by changing drainage patterns, blocking overland flow, and increasing local ponding.

Population growth and development can fragment or remove natural ecosystem functions, such as naturally occurring wetlands that hold, store, and slowly release runoff. Loss of wetlands significantly increases flood losses within adjacent properties and beyond.

FIGURE 30. AN ATHLETIC FIELD AT A FRIENDSWOOD, TEXAS JUNIOR HIGH SCHOOL BEING USED AS A DETENTION POND DURING HURRICANE HARVEY, 2017. SOURCE: W. HIGHFIELD, TEXAS A&M.

FROM THE COMMUNITY

"As communities move forward with their planning processes, planning for stormwater should not be ignored. Stormwater management must be part of the overall planning/zoning process. Stormwater management is not only about considering the flooding potential within FEMA-designated floodplains adjacent to creeks and rivers or designing a drainage system to convey the standard 10yr event, it is also about understanding the characteristics of each watershed and how new development can create its own microcosm of flooding potential, be it 640 acres or only 6.4 acres. As we reshape the land and install drainage systems that are typically designed to convey runoff well below the ever-increasing intensities that are becoming more the norm than not, we must always ask ourselves, how does the stormwater find relief? If overland relief is ignored, then that new roadway can become a dam for tomorrow's miniature urban reservoir of flooding. If flood-prone areas are not protected and allowed to be filled, be they FEMA or local, then what we thought was flood-prone is actually larger and the impacts and the costs become unmanageable."

CAPTURING RAIN WHERE IT FALLS

Many cities and towns across the United States are giving considerable attention to plans that support the capture of rain in areas where it falls. The use of building codes that eliminate increases in runoff from newly constructed properties, the assessment of stormwater fees based on the amount of infiltration that takes place on a given piece of property, and actions by individual home and business owners such as rain gardens, green roofs, rain barrels, etc. can significantly reduce the volume and timing of intense rainfall runoff. Carefully designed bioswales and detention (Figure 30) and retention ponds can make even larger contributions to runoff reduction. The EPA offers considerable information about such activities.[22]

FIGURE 31. SANDBAGS BLOCKING STORMWATER FLOW FROM WASHINGTON METRO SUBWAY AIR VENT. SOURCE: G. GALLOWAY, UMD.

FIGURE 32. PERMANENT PROTECTION FOR WASHINGTON METRO SUBWAY VENT. SOURCE: WASHINGTON METROPOLITAN AREA TRANSIT AUTHORITY.

ELIMINATING OR REDUCING THE RISK OF FLOODING

A challenge for older communities are areas where significant improvement in drainage is too costly to be considered. In these cases, elevation of the structures where such efforts are economically feasible or "buying out" properties at risk should be considered. Elevating a structure does not guarantee its safety, but when the height of elevation is carefully considered, it can significantly reduce the threat to the property (and reduce insurance costs). By removing a property from a flood-prone area, buyouts eliminate future losses, can create green space to support retention or detention areas, and offer space for community recreation.

ADEQUATE MAINTENANCE

Many of the problems associated with urban flooding can be addressed with techniques well known to those responsible for storm and floodwater management systems. Unfortunately, almost all of these techniques require resources to carry them out. Often, the manpower and the dollars to address these issues are absent from budgets or at the bottom of the priority list. As indicated in an earlier section, maintenance of stormwater systems is extremely important; a failure to carry out needed maintenance or replace aging systems creates repetitive challenges for the community. Some of the maintenance requirements can be reduced through local resident participation in maintenance activities, such as clearing drains of debris or reporting such problems as they occur, prior to storm events. Community outreach can alert citizens of their responsibilities and demonstrate how their actions can provide benefits for the entire community.

Actions can also be taken at the individual home or business level to reduce urban flooding. Egresses can be blocked either permanently or temporarily to prevent flood waters from entering and flooding basements and the upper floors. Losses to high-value items can be reduced by moving them to higher elevations within the structure. FEMA and USACE provide extensive literature on how to "flood proof" properties.[23] Innovative and simple solutions, such as sandbagging openings to below-ground utilities or other activities, can substantially reduce losses (Figure 31). More permanent solutions (Figure 32) reduce the labor costs involved in periodic use of interventions, like sandbags.

A significant problem in many communities is backup of sewage from sewer line connections into homes and businesses when combined or sewage-only systems are overtaxed. These problems can normally be addressed by use of backflow prevention valves (Figure 33).

Many homeowners and renters living and working in areas affected by urban flooding do not understand that they, individually, can take steps to significantly reduce their property's vulnerability. Many lack the resources and support necessary to carry out such actions. Information on how residents can reduce their property's flood risk frequently is not accessible or well-articulated.

UPGRADING OF CAPACITY STANDARDS

A failure to upgrade current storm and wastewater capacity standards places communities and their citizens at risk. Most older stormwater, wastewater, and combined systems that were designed with limited capacity have become overwhelmed by flow increases spurred by hydrologic change and urban growth. Systems designed to handle the five-year storm are inundated by current conditions; the potential for significant increases in the size and scope of future rainfall events put even seemingly high-capacity systems at risk. Individuals designing systems that deal with riverine and coastal flooding face the same challenges and are moving rapidly to address them. Again, because of the diverse nature of the urban flooding community, collaborative action is often not being taken to develop modern capacity standards.

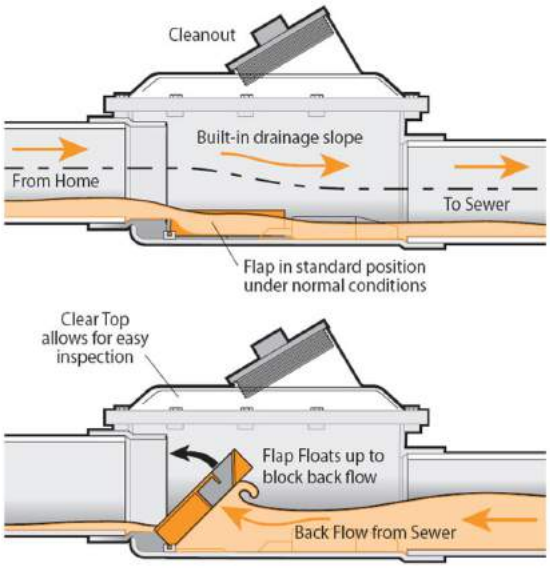


FIGURE 33. TYPICAL BACKFLOW PREVENTION VALVE DESIGNED TO PREVENT SEWAGE FROM BACKING FROM SEWAGE SYSTEM INTO PROPERTY. SOURCE: SQUARE ONE INSURANCE SERVICES, SQUAREONEINSURANCE.COM.

RISK COMMUNICATION: GAINING PUBLIC UNDERSTANDING

A majority of residents in urban flood-prone areas generally do not understand the actual risks (nature of hazard, consequences, and probabilities of occurrence) that they face from urban flooding. Also, in many cases, public officials are not doing an effective job of getting the word out. Of the 227 survey respondents, 58% reported this condition in the communities they represented. Numerous federal reports over the last decade have indicated that miscommunication is a significant challenge in all types of flooding. The most common response by those "caught off guard" by unexpected flooding was, "I just did not know that I was at risk; nobody told me." For decades, people living in flood-prone areas have relied on NFIP maps to determine if they were at risk (i.e., in the SFHA and needed to buy insurance). However, since FEMA NFIP flood maps do not normally provide adequate information concerning flood risk in urban flood zones and most communities do not actively publicize the location of such areas, occupants are ill-informed about any risks.

There is no simple approach to identifying and assessing urban flood risk and communicating that risk to those who are affected. Since a significant amount of urban flooding may occur outside the bounds of the SFHA (that is delineated by the 100-year flood under the NFIP), there is currently no tool available to communities to assist in similarly delineating potential levels of urban flood risk.

FIGURE 34. HIGH WATER MARK SIGN IN CEDAR RAPIDS, IOWA. SOURCE: KCRG-TV.

Use of high-water mark signs (Figure 34) that identify the height of historical floods can also alert residents to their risks and lead them to possible mitigation methods. However, in many communities, public officials and current residents object to the use of such signs which are seen to devalue the nearby property.

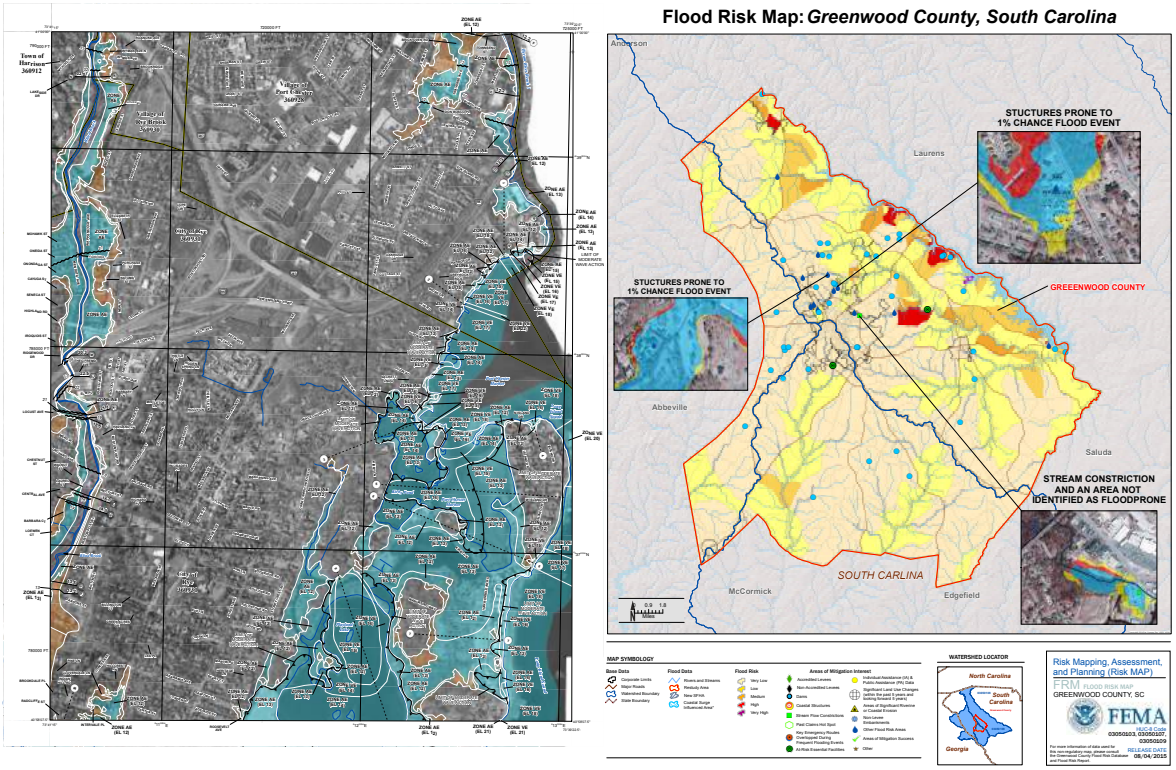


FIGURE 35. LEFT MAP: A FEMA FLOOD INSURANCE RATE MAP IDENTIFYING SFHA (ZONES AE AND VE) AND ZONE X (500-YEAR FLOODPLAIN IN ORANGE COLOR) AND AREAS BEYOND. RIGHT MAP: A FEMA FLOOD RISK MAP IDENTIFYING FIVE LEVELS OF RISK FROM "VERY HIGH" (PURPLE SHADING) TO "VERY LOW" (YELLOW SHADING). SOURCE: FEMA. THIS PRODUCT USES THE FEDERAL EMERGENCY MANAGEMENT AGENCY'S API, BUT IS NOT ENDORSED BY FEMA.

FIGURE 36. MAP ON LEFT IS A FIRM FOR A NEIGHBORHOOD IN A TEXAS COMMUNITY. THE GRAY SHADING INDICATES THE SFHA IN THAT AREA. THE RED BOX IDENTIFIES THE LOCATION OF THE AREA SHOWN IN THE RIGHT MAP WHERE, DUE TO PROBLEMS WITH THE LOCAL DRAINAGE, THE AREAS SHOWN IN BLUE ARE SUBJECT TO URBAN FLOODING BUT NOT REFLECTED ON THE FIRM. SOURCE: THE ASSOCIATION OF STATE FLOODPLAIN MANAGERS ANNUAL CONFERENCE, 2018.

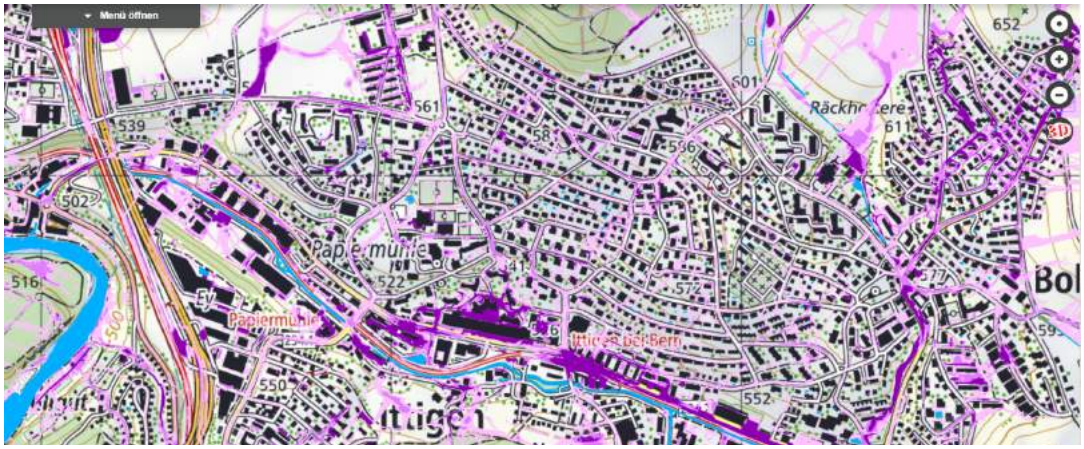


FIGURE 37. SWISS SURFACE RUNOFF HAZARD MAP. THE DARKER THE SHADE OF PURPLE SHOWN, THE HIGHER THE WATER LEVEL IS PREDICTED TO RISE DURING A FLOOD. SOURCE: © DATA: SWISSTOPO, FOEN.

MAPPING URBAN FLOOD ZONES

Flood Insurance Rate Maps (FIRMs) identify SFHAs and guide the development of flood insurance rates under the NFIP. They have also been incorrectly seen as tools to communicate basic flood risk—property is subject to flooding (in the SFHA) or not (outside the SFHA).[24] To better communicate risk, FEMA, under the Risk MAP program, has developed a set of mapping products that better convey flood risk messages to the public, although none have been accepted as substitutes for FIRMs. These products, where SFHA may not even be mentioned, offer some ideas on how best to portray urban flood risk (Figure 35). Pilot programs, such as one being examined by a Texas community (Figure 36), can identify, through use of high-resolution models, areas of potential urban flooding.

Switzerland's government recently launched a website entitled "Hazard Map Surface Drainage Switzerland" that provides a map of areas in Switzerland that are potentially affected by major surface rainfall runoff. The objective of this mapping is not to offer high-resolution information about flooding depths, but instead focus on providing "stakeholders, such as builders, planning and architecture offices, building authorities, natural hazard departments, civil protection, insurance companies, and others with a basis to help them recognize the dangers at the early stage and to prevent damage with appropriate measures." The maps (Figure 37) that were developed through a partnership between the Swiss government and Swiss insurance associations are not legally binding documents but alert users to the challenges they face. Switzerland reports that "up to half of all floods in Switzerland are not caused by overflowing rivers and lakes, but by excess rainwater not being absorbed into the ground [emphasis added]."[25]

NASA is supporting a program called "Monitoring Urban Floods Using Remote Sensing," which uses space resources to identify flooded urban areas on a timely basis. Because satellites are continuously observing various locations, a time series of flood activity can easily be developed. Planners and managers can begin to identify areas of frequent inundation and long-term risk. Smaller communities that lack the resources to carry out their own image acquisition through commercial sources can take advantage of NASA's efforts.[25]

FROM THE COMMUNITY

"NFIP FIRM maps, although useful to some extent, have done somewhat of a disservice in communicating flood risk to the general public. There is a sense that if I'm in the SFHA, I'll be flooded and if I'm out of the SFHA, I won't ever be flooded. Further FIRM maps (at least in the Midwest) imply that flooding only occurs in riverine scenarios, and not in local areas."

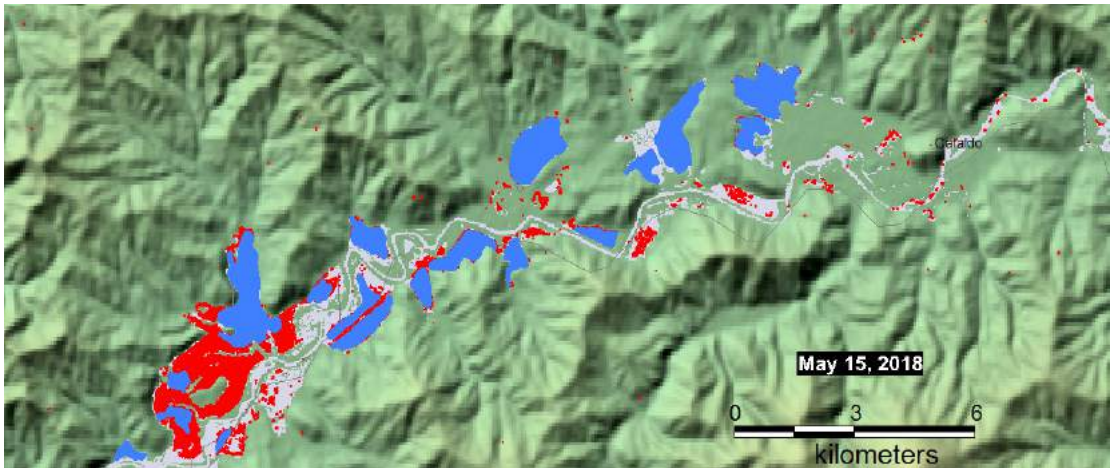


FIGURE 38. NASA HIGH ALTITUDE FLOOD MONITORING. "RED IS FLOOD MAPPED FROM COPERNICUS SENTINEL 1 SAR DATA PROVIDED BY THE EUROPEAN SPACE AGENCY. BLUE IS A REFERENCE NORMAL WATER EXTENT (SWBD). LIGHT GRAY IS ALL PREVIOUSLY MAPPED FLOODING. FOR THIS SAR-BASED MAPPING, A CHANGE DETECTION METHOD IS USED (GIS FILE NAMES SHOW COMPARISON IMAGE DATES). TOP: COEUR D'ALENE RIVER, FALSE COLOR COMPOSITE USING DATA FROM SEPTEMBER 27, 2017 (BEFORE) AND MAY 15, 2018 (DURING). THE 10 M. RESOLUTION OF THE SAR IMAGE HAS BEEN SOMEWHAT DEGRADED BY APPLICATION OF A 5X5 LOW PASS FILTER TO REDUCE SPECKLE. A BAND RATIO AND FLOOD IMAGE INTENSITY ALGORITHM ARE USED TO IDENTIFY NEW WATER, ALREADY VISIBLE IN THE SAR IMAGE ITSELF AS RED COLORS." SOURCE: DARTMOUTH FLOOD OBSERVATORY AT THE UNIVERSITY OF COLORADO, FROM SATELLITE DATA PROVIDED BY NASA AND COPERNICUS/EUROPEAN SPACE AGENCY.

Many flood and stormwater communities have suggested that mapping of urban flood zones be added to the mapping program of the NFIP, as FEMA is already involved in such activity. Others have argued that identification of urban flood zones should be the responsibility of local governments, which have intimate knowledge of the needs of the community and how best to convey the information. In addition, the latter group indicates that moving urban flood zone determination and mapping into an already complicated federal-state-local process would add significant burdens to communities and that the methodology for determining levels of risk are significantly different in urban versus riverine and coastal areas. Urban floods are generally tied to heavy rainfall events as opposed to river and coastal waters flood events, and movement of the rainfall runoff through stormwater structures, streets, natural drainage, and open channel infrastructure, all of which are subject to disruptions (e.g., culvert and pipe blockages, neighborhood back-ups, etc.), are not normally accounted for in riverine flood frequency determinations. As gleaned in recent urban floods across the country, it is extremely difficult to determine the recurrence interval of an urban flood event. A 100-year urban flood event that is in reality a 100-year rainfall event is difficult to compare to a 100-year event in the riverine and coastal context.

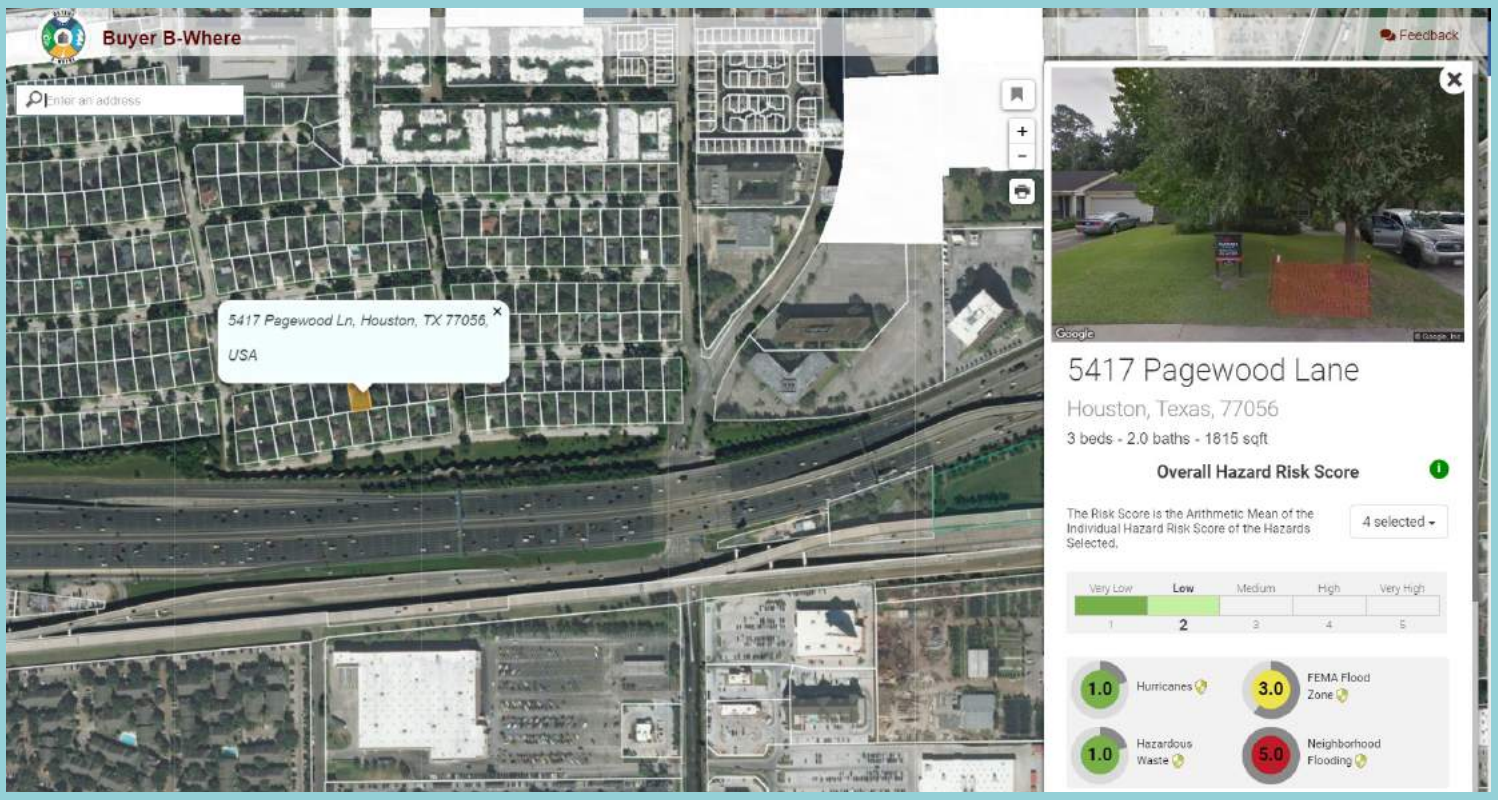


FIGURE 39. AN ILLUSTRATIVE PANEL FROM THE BUYERS BE-WHERE SOFTWARE FOR THE PROPERTY INDICATED. THE PANEL PROVIDES INFORMATION ON SEVERAL LOCAL HAZARDS. SOURCE: BUYERS-BEWHERE.COM.

DISCLOSING RISKS IN USER-FRIENDLY WAYS

Renters and buyers of property in an urban flood zone are faced with a lack of available information about flood risk or even previous flood history. Some states require that the seller or the agent formally disclose to the buyer or renter that the property is in the SFHA. Lenders can require that elevation certificates be provided to indicate that the property is not in the SFHA, but again, these provisions are applicable to property where the SFHA has been mapped. In the urban case, no such map exists, and the tools for identifying risk have not been developed.

Software programs, such as Texas A&M University's "Buyers Be-Where" (Figure 39), could be used to disseminate urban flood risk information (Buyers-bewhere.com). However, because such information is often seen as having negative consequences on the economic viability of community development, public officials are frequently reluctant to "push" the information to the public, preferring to make it available only to those who know of its existence and ask for it. As a result, potential home buyers or renters often move into an area and are blindsided when floods occur. Another available risk disclosure tool is FloodTools (floodtools.com) (Figure 40). Operated by National Flood Services, it provides risk information on properties in all states, including maps of previous flood events.

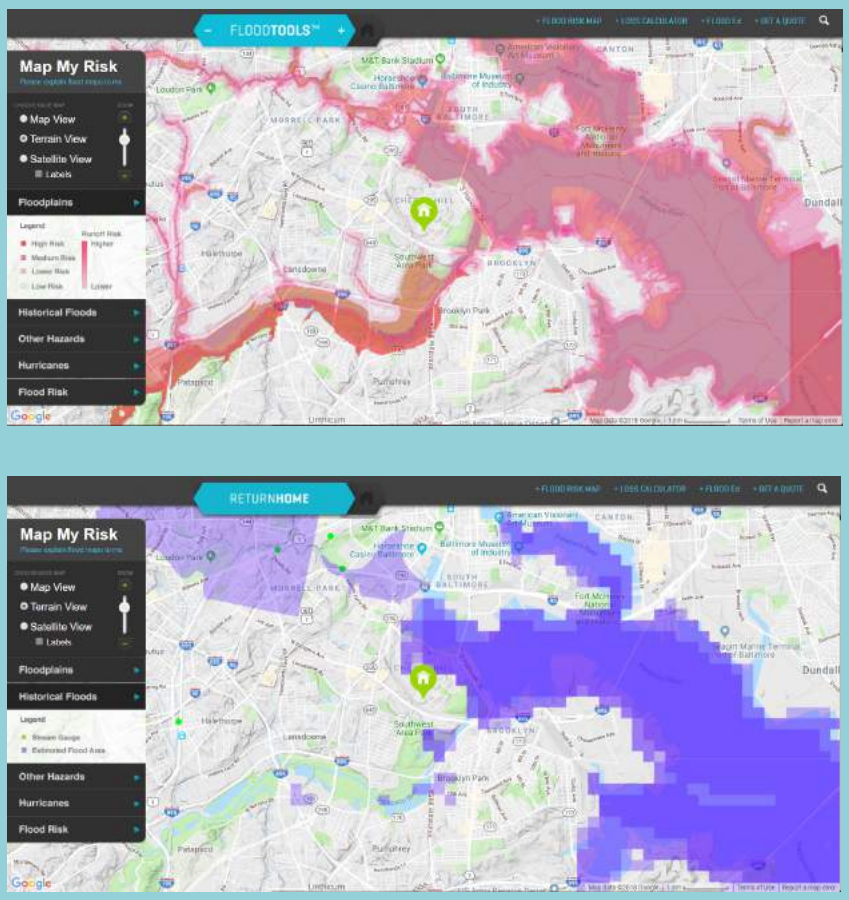


FIGURE 40. ILLUSTRATIVE PANELS FROM THE FLOODTOOLS SOFTWARE FOR THE PROPERTY INDICATED. THE TOP PANEL PROVIDES INFORMATION ON THE FLOOD RISK, AND THE LOWER PANEL PROVIDES A HISTORY OF FLOODING. SOURCE: FLOODTOOLS.COM.

INSURING AT-RISK PROPERTIES

Purchase of insurance is a significant means of reducing the flood risk of individuals and businesses, but many in urban flood-prone areas do not purchase it because it is seen as unaffordable. Most property owners or rental occupants at risk do not understand how insurance works or understand the risks they face.

A key consideration in bringing insurance to urban flood risk zones is the fact that when a community joins the NFIP and a FIRM is prepared, the entire community, in or out of the SFHA or marked zones, is eligible to purchase insurance. This means that occupants of scattered flood-prone 'islands' within the community can obtain insurance, generally at low rates. Community programs that encourage the purchase of flood insurance in areas outside the SFHA can be successful and reduce the risk to those that purchase insurance.

FROM THE COMMUNITY

"Lack of funding and lack of political will are the most significant issues. Much of the available funding requires a cost share and significant participation in the NFIP program. Most properties outside the mapped floodplain do not carry flood insurance. This then requires localities to fund these initiatives by themselves. Additionally, new development outside the floodplain generally has limited stormwater control requirements. Local CEOs are often reluctant to require stormwater controls as they fear this would dissuade development."

VII. MAJOR CHALLENGES

While there are many approaches to reducing the risk of urban flooding and every community must develop its own plan to deal with its unique risk, it is obvious that communities face common challenges that extend beyond better engineering and planning.

PENSACOLA, FLORIDA, PHOTO BY ANDREA BOOHER/FEMA

LACK OF RESOURCES

Communities across the country lack the resources to effectively operate, maintain, and upgrade their water, wastewater, and stormwater systems, and to manage the urban flooding that occurs as a result of the shortfall; there are limited federal programs to support such activities. The 2017 American Society of Civil Engineers infrastructure report card assigns a grade of D+ to wastewater/stormwater systems across the nation. Of the 305 reporting communities surveyed, 41% indicated that funding was the principal bar to moving forward with urban flood mitigation. At the individual level, most homeowners or renters lack the resources and/or the knowledge to address flooding issues that are primarily structure focused, such as sewage and stormwater backup. A recent Canadian report indicated that the risk of damage to homes from sewer backups alone "could be eliminated through the installation of a backwater valve…[and] the preventable damage to homes is greater in any recent year than the cost of purchasing a backwater valve for every home in Canada."[27]

While there are federal and state grant and loan programs to address water, wastewater, stormwater, and flood infrastructure, the amounts available fall far shy of the amounts needed. Recent attention to urban flooding indicates that addressing this flooding will significantly increase the demand for funds.

POPULATION AND URBAN GROWTH

Increasing population in urban areas is exacerbating urban flooding problems. Those at the lowest end of the economic spectrum face the challenge of finding the least expensive housing, often moving into basements or other areas subject to more frequent flooding. Even public housing faces these flooding challenges.

CLIMATE CHANGE

The 2017 National Climate Assessment indicates that major rainfall events are continuing to increase in many parts of the country and that these increases will result in more urban flooding.

The assessment finds that:

"Heavy downpours are increasing nationally, especially over the last three to five decades. The heaviest rainfall events have become heavier and more frequent, and the amount of rain falling on the heaviest rain days has also increased. Since 1991, the amount of rain falling in very heavy precipitation events has been significantly above average. This increase has been greatest in the Northeast, Midwest, and upper Great Plains – more than 30% above the 1901-1960 average...Flooding may intensify in many U.S. regions, even in areas where total precipitation is projected to decline.

Urban flooding can be caused by short-duration, very heavy precipitation. Urbanization creates large areas of impervious surfaces (such as roads, pavement, parking lots, and buildings) that increased immediate runoff, and heavy downpours can exceed the capacity of storm drains and cause urban flooding. Flash floods and urban flooding are directly linked to heavy precipitation and are expected to increase as a result of increases in heavy precipitation events."

FROM THE COMMUNITY

"Challenges of urban flooding include large public cost of numerous small projects to minimize or reduce flood risk to a few affected private properties. Because retrofit storm sewer upgrades are expensive and usually disruptive, they are not as highly prioritized as major stormwater projects such as arterial roadway bridge or culverts, regional detention ponds, etc. Often the repetitive flooding has been going on for so many years in older areas of towns, that it is just considered business as usual, even for the property in some cases."

Sea level rise is occurring around the globe, and while much attention is being paid to the impacts on major coastal cities of the world, sea level rise will also affect the thousands of smaller communities that exist along our shorelines. The increase in sea level in itself will flood many coastal areas. In addition, sea level rise will cause significant challenges to the drainage systems in coastal communities; infrastructure built to conditions of a century ago will no longer be able to operate.[28]

While professionals dealing with urban flooding at the local level are aware of the challenge of climate change, including sea level rise, those they work for and the public at large may not be as cognizant of the implications of climate change. More than 60% of the reporting communities indicated they were taking future conditions into account in planning required upgrades and new work; however, the lack of public understanding of the potential impacts of climate change are limiting public support for such climate change-related activity and any funding increases that would be required to address climate change.

PRIORITY SETTING

Because urban flooding may cover only selected areas in a community, it is frequently of less concern to those not effected. It gets less attention from public officials and the public in general until a major event creates a significant disruption. Many urban floods involve only a small percentage of a large community and affect segments of the community in lower-valued properties. Occurrences are not headlined in newspapers or the focus of major governmental actions. Seventy percent of survey respondents (n=345) indicated the urban flooding was a significant concern of those affected, but only 34% indicated that elected officials and the community, in general, saw it as a matter of importance. Twenty-eight percent of the respondents noted that the community saw urban flooding only as a nuisance.

CHICAGO, ILLINOIS, PHOTO COURTESY OF CNT/RAINREADY

GOVERNANCE

The management and oversight of activities related to urban flooding are scattered throughout governmental entities at all levels. The dispersal of responsibilities creates overlaps in actions and limits progress in resolving urban flooding issues.

It is clear that professionals involved in urban flood mitigation and in water, wastewater, and stormwater management believe that the principal responsibility for management of urban flooding and related aspects of flood and stormwater management should be at the local level. It is at this level where the problem is best understood; however, local efforts should be supported by state and federal agencies with regards to the fiscal challenges in the management and integration of other related state and federal programs. There are significant challenges in sorting out the responsibilities of the multiple agencies that act at the municipal level in the water, wastewater, and flood management arenas. In many places, municipal flood management is separated from municipal stormwater management and the programs are frequently in conflict. A report by the state of Illinois on urban flooding and the results of a symposium held by the Illinois Association for Flood and Stormwater Management clearly defined many of these challenges at the state and local level.[29]

Observation:

There is no federal agency charged with oversight of federal support of urban flood mitigation-related activities.

At the federal level, the responsibility for urban flooding is not clear. The USACE is seen to have principal responsibility for major flood risk reduction activities and focuses its activities on prevention of damage from riverine and coastal floods. When a major river or bayou flows through an urban area, as they do in the Houston metropolitan region, USACE may participate in urban flood reduction activities. However, under USACE regulations, the discharge of a stream or a waterway creating this urban flooding must be in excess of 800 cubic feet per second or the 10-year flood, which severely limits USACE participation in urban activities.

FEMA operates the NFIP and is responsible for federal actions in response to disasters, which normally require a Presidential Disaster Declaration of their severity and, as a result, dramatically limits federal fiscal support in limited-area flood events where statewide impact is low. FEMA requires control by local communities of floodplain management activities in coastal and riverine SFHAs and, to a considerably lesser degree, in the 500-year floodplain, where they pose little or no restrictions on development. Most people in an urban area, where the community participates in the NFIP, are eligible to purchase flood insurance, but since the NFIP is focused on riverine and coastal flooding, little attention is given to increasing participation by urban community members in the NFIP insurance program.

The EPA has principal responsibility for water quality and provides national oversight on activities related to the treatment and disposal of waters in urban areas. However, the EPA does not fully integrate floodwater and floodplain management into the activities they guide or support. Over the last decade, the EPA has put considerable attention into separating urban stormwater flows from urban wastewater flows to prevent the former from becoming carriers of pollution during major storm events. However, little attention has been given to integrating the stormwater system solutions with related floodplain risk reduction systems. In a 2009 National Research Council study on stormwater for the EPA, the primary focus was on water quality, seemingly portraying wastewater as distinct from stormwater in the management of urban water challenges. [30]

While primary responsibility for urban flood mitigation rests at the local level, the federal government is already operating programs for riverine and coastal flood risk reduction and stormwater management; these programs are inextricably linked to urban flooding and need coordination both at the federal level and with state and local governments. The administration, in coordination with Congress, should convene a forum of representatives from state and local governments, Indian tribes, nongovernmental organizations, and the public to develop a national "suite of actions" to mitigate urban flooding and identify responsibilities at each level of government.

ENDNOTES

[1] Story to remember, 2014: August flooding in metro Detroit, Originally Published: December 22, 2014 12:00 PM Modified: December 22, 2014 12:00 PM. Crain's Detroit Business. http://www.crainsdetroit.com/print/612236; United States Flood Loss Report – Water Year 2014. NWS.

[2] http://www.nws.noaa.gov/os/water/Flood%20Loss%20Reports/WY14%20Flood%20Loss%20Summary.pdf; FEMA; Michigan – Severe Storms and Flooding Declaration FEMA-4195-DR Declared September 25, 2014. https://www.fema.gov/disaster/4195.

[3] Harriet, Festing. "The Prevalence and Cost of Urban Flooding - A Case Study of Cook County, IL." Center for Neighborhood Technology, May 2013.

[4] Laura Lightbody & Forbes Tompkins. Pew Trust. After 1,000-Year Flood, Baton Rouge Moved Fast to Lower Risk. May 14, 2018. http://www.pewtrusts.org/en/research-and-analysis/articles/2018/05/14/after-1000-year-flood-baton-rouge-moved-fast-to-lower-risk.

[5] How Ellicott City Flooded: A Timeline. Baltimore Sun. June 1, 2018. https://www.baltimoresun.com/news/weather/bs-md-ellicott-city-flooding-timeline-20180530-story.html; Series of powerful thunderstorms unleash on Des Moines metro. KCCI Des Moines. July 1, 2018. https://www.kcci.com/article/strong-to-severe-thunderstorms-are-firing-up-across-iowa/22008026.

[6] Colorado woman drowns in flooded basement. Canoe News World' July 26, 2018. Associated Press. https://canoe.com/news/world/colorado-woman-drowns-in-flooded-basement.

[7] DJ Nowak, JT Walton. 2005. Projected urban growth (2000–2050) and its estimated impact on the US forest resource. Journal of Forestry, - academic.oup.com.

[8] NWS Hydrologic Information Center – Flood Loss Data. http://www.nws.noaa.gov/hic.

[9] Report for the Urban Flooding Awareness Act. State of Illinois, Department of Natural Resources. June 2015. https://www.dnr.illinois.gov/waterresources/documents/final_ufaa_report.pdf. In PA98-0858, the Urban Flooding Awareness Act, the Illinois Legislature defined urban flooding as "The inundation of property in a built environment, particularly in more densely populated areas, caused by rainfall overwhelming the capacity of drainage systems, such as storm sewers. 'Urban flooding' does not include flooding in undeveloped or agricultural areas. 'Urban flooding' includes (i) situations in which stormwater enters buildings through windows, doors, or other openings, (ii) water backup through sewer pipes, showers, toilets, sinks, and floor drains, (iii) seepage through walls and floors, and (iv) the accumulation of water on property or public rights-of-way."

[10] Report for the Urban Flooding Awareness Act.

[11] Report for the Urban Flooding Awareness Act.

[12] Groisman, P.Y., R.W. Knight, D.R. Easterling, T.R. Karl, G.C. Hegerl, and V.N. Razuvaev, 2005: Trends in Intense Precipitation in the Climate Record. Journal of Climate, 18(9): p. 1326-1350.

[13] http://www.detroitmi.gov/How-Do-I/Find/DWSD-Alerts-and-News/ArticleID/1404/DWSD-Launches-Program-to-Clean-and-Inspect-30-000-Catch-Basins.

[14] Craig, T. August 9, 2017. The Washington Post. It wasn't even a hurricane, but heavy rains flooded New Orleans as pumps faltered. https://www.washingtonpost.com/national/it-wasnt-even-a-hurricane-but-heavy-rains-flooded-new-orleans-as-pumps-faltered/2017/08/09/b3b7506; Nicole Chavez and Michelle Krupa. August 12, 2017. New Orleans flooding and pumping system crisis by the numbers. CNN. https://www.cnn.com/2017/08/11/us/new-orleans-flooding-by-the-numbers/index.html.

[15] Kovacs, Paul, Sophie Guilbault and Dan Sandink. 2014. Cities Adapt To Extreme Rainfall: Celebrating Local Leadership. Institute for Catastrophic Loss Reduction, Toronto.

ATTENTION TO ENGINEERING AND SCIENCE

Over the last five decades, considerable attention has been given to improving the science and engineering connected with the management of floods and the employment of the multiple tools available to reduce flood risk and to prevent significant flood events. Unfortunately, there have been no similar efforts in the area of urban flooding. Several areas in need of attention emerged during this study.

DATA AVAILABILITY AND SYNCHRONIZATION

Technical and demographic data concerning urban flooding is scattered among many agencies and is captured and stored in differing formats, thereby limiting analysis and development of high-quality solutions. Agencies are protective of data that they have collected and analyzed and are often reluctant to share with other entities. However, without complete watershed-level information, reliable solutions will not be developed. Privacy act restrictions frequently reduce the number of datasets available for analysis, when, after carefully planned scrubbing, data might be made available without jeopardizing privacy.

MODEL ORDINANCES

Model ordinances provide great assistance to communities that lack the capacity to develop their own. Because solutions to urban flooding are at the intersection of several sub-disciplines, each with its own constituency, it is difficult to find a single model ordinance that would satisfy all needs across the spectrum of challenges that must be faced; therefore, it may be necessary to develop a suite of such ordinances. Development will require a collective action by professional organizations that deal with floodplain management, stormwater management, and water and wastewater management, as well as other organizations that influence urban planning and design.

URBAN FLOOD MODELS

Efforts over the last decades have focused on improving the plethora of hydraulic and hydrologic models available in support of watershed management, systems analyses, engineering design, and standards development. Considerably less attention has been given to the development of models that examine the urban environment. To identify urban flood potential under intense rainfall events, New York City recently made use of models that offer new techniques and follow-on analysis illustrating spatial flood dynamics over time (Figure 41).

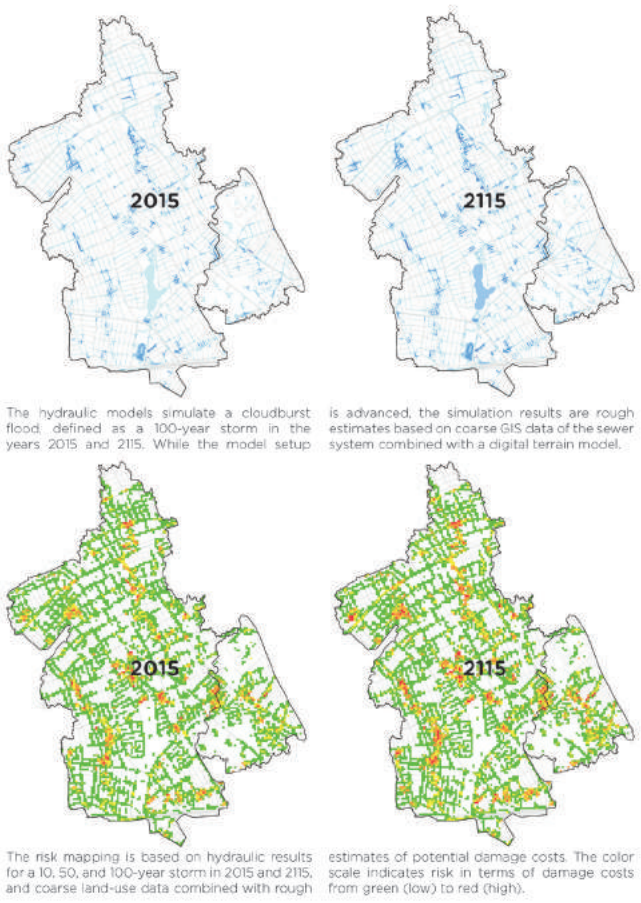


FIGURE 41. NEW YORK CITY URBAN FLOOD MODELING. SOURCE: NEW YORK CITY DEPARTMENT OF ENVIRONMENTAL PROTECTION, JANUARY 2017. CLOUDBURST RESILIENCY PLANNING STUDY. PREPARED BY RAMBOLL A/S.

[16] NWS Hydrologic Information Center – Flood Loss Data. http://www.nws.noaa.gov/hic/. "The National Weather Service's primary mission is to provide weather information for the protection of life and property. Ancillary to this mission, NWS field offices provide loss estimates for significant flood events. No one governmental agency has specific responsibility for collecting and evaluating detailed flood loss information. Therefore, the resulting data are to be considered rough estimates, and may be unrepresentative of actual damages."

[17] Low income not same in survey as in Department of Commerce definition.

[18] Population in the U.S Floodplains - Furman Center. http://furmancenter.org/files/Floodplain_PopulationBrief_12DEC2017.

[19] Harriet, Festing. "The Prevalence and Cost of Urban Flooding - A Case Study of Cook County, IL." Center for Neighborhood Technology, May 2013.

[20] Harriet, Festing. "The Prevalence and Cost of Urban Flooding - A Case Study of Cook County, IL." Center for Neighborhood Technology, May 2013.

[21] USACE Value to the Nation. http://www.corpsresults.us/flood/floodcalculate.cfm; https://www.iwr.usace.army.mil/Portals/70/docs/VTN/VTNFloodRiskMgmtBro_loresprd.pdf.

[22] EPA. 2009 Stormwater Wet Pond and Wetland Management Guidebook. https://www3.epa.gov/npdes/pubs/pondmgmtguide.pdf.

[23] FEMA. September 2015. Reducing Flood Risk to Residential Buildings that Cannot Be Elevated. FEMA P-1037 https://www.fema.gov/media-library-data/1443014398612-a4dfc0f86711bc72434b82c4b100a677/revFEMA_HMA_Grants_4pg_2015_508.pdf; USACE. National Nonstructural Committee (NNC). https://www.usace.army.mil/Missions/Civil-Works/Project-Planning/nfpc/.

[24] National Research Council. 2013. Levees and the National Flood Insurance Program: Improving Policies and Practices. Washington: National Academy Press.

[25] Switzerland. Federal Office for the Environment. 2018. Prepared for heavy precipitation: The new hazard map Surface Runoff Switzerland. https://www.bafu.admin.ch/bafu/de/home/themen/naturgefahren/dossiers/gefaehrdungskarte-oberflaechenabfluss.html.

[26] NASA. 2018. Urban Flood Monitoring Using Remote Sensing Observations. https://arset.gsfc.nasa.gov/sites/default/files/disasters/urban-flood-18/urban-flood-week2.pdf.

[27] Kovacs, Paul, Sophie Guilbault and Dan Sandink. 2014. Cities Adapt To Extreme Rainfall: Celebrating Local Leadership. Institute for Catastrophic Loss Reduction, Toronto.

[28] Matthias Mengel, Anders Levermann, Katja Frieler, Alexander Robinson, Ben Marzeion, and Ricarda Winkelmann. Future sea level rise constrained by observations and long-term commitment. PNAS March 8, 2016. 113 (10) 2597-2602.

[29] Illinois Flood Risk Symposium. Urban Flood Risk. Chicago, IL. February 2015 - ASFPM Foundation. http://www.asfpmfoundation.org/ace.

[30] National Research Council. 2009. Urban Stormwater Management in the United States. Washington: National Academy Press.

VII. MOVING AHEAD: CONCLUSIONS AND RECOMMENDATIONS

THE STUDY TEAM CONCLUDED THAT:

1. **In much of the United States, urban flooding is occurring and is a growing source of significant economic loss, social disruption, and housing inequality. Extensive suburban development that creates higher flood flows into urban areas, aging and frequently undersized infrastructure in older sections of communities, an inability to maintain existing drainage systems, increases in intense rainfall events, and uncoordinated watershed management all contribute to these increases in urban flooding.**

2. **The growing number of extreme rainfall events that produce intense precipitation are resulting in—and will continue to result in—increased urban flooding unless steps are taken to mitigate their impacts. The 2017 National Climate Assessment concluded that "heavy downpours are increasing nationally, especially over the last three to five decades…[and that]… increases in the frequency and intensity of extreme precipitation events are projected for all U.S. regions."**

3. **Communities across the nation are facing similar challenges with urban flooding. However, the unique hydrological, physical, and social characteristics of these communities mean solutions are best developed locally. While the magnitude of urban flooding challenges merit federal guidance and support when needed, responsibilities must rest primarily at the local level.**

4. **While primary responsibility for mitigation of urban flooding rests with local governments, the division of responsibilities among federal, state, regional, local, and tribal governments for urban flood and stormwater management are not clearly defined. Responsibilities are diffused and lack the collaboration and coordination necessary to address the technical and political challenges that must be faced.**

5. **Many of the urban wastewater and stormwater systems that provide the backbone of urban flood mitigation are in poor condition and—in some locations—are inadequate and in need of strong support. The human and fiscal resources necessary to address urban flooding are not generally available at the levels required.**

6. **At the federal level, there is no agency charged with oversight of federal support of urban flood mitigation-related activities. While primary responsibility for urban flood mitigation rests at the local level, the federal government is already operating programs for riverine and coastal flood risk reduction and stormwater management; these programs are inextricably linked to urban flooding.**

7. **The economic and social impacts of urban flooding are generally not well known and understood by many public officials and the unaffected public. Social vulnerabilities and inequities in disaster recovery for low-income populations are not being fully addressed.**

8. **Governments, at all levels, have not provided effective means to communicate risks to those in urban flood-prone areas. A significant number of these areas are not identified by maps produced under the Federal Emergency Management Agency National Flood Insurance Programs, and actions by those responsible for urban flood mitigation are needed to delineate these areas. Communication of flood risk is often seen by public officials and developers as a negative.**

9. **Many homeowners and renters living and working in areas affected by urban flooding do not understand that they can take steps to significantly reduce their property's vulnerability, and many lack the resources and support necessary to carry out such actions. Information on how a resident can reduce their property's flood risk is not accessible or well-articulated.**

10. **Data—covering insurance claims, assistance, and loans for flood mitigation—are not easily available or shared with local decision-makers, researchers, and the residents themselves. More accessibility and availability of data is critical to effective response, recovery, and long-term mitigation of flood events. This data must be provided in an easily interpreted and spatially identifiable format.**

THE STUDY TEAM RECOMMENDS THAT:

1. **Governors, tribal leaders, and regional and municipal officials should review the current responsibilities for oversight of urban flooding mitigation, as well as flood, water, wastewater, and stormwater management in their jurisdictions; provisions, as appropriate, should be made to ensure efficient and effective multi-jurisdictional planning and operation of these activities and services on a geographic scale that matches the problems being addressed.**

2. **The administration, in coordination with Congress, should convene a forum of representatives from state and local governments, Indian tribes, nongovernmental organizations, and the public to develop a national "suite of actions" to mitigate urban flooding and identify responsibilities at each level of government.**

3. **The administration, in coordination with Congress, should assign one federal agency to provide interim oversight of federal support of urban flood mitigation activities, the development of the national forum, and the preparation of a post-forum report for the administration, Congress, the states, municipalities, and tribes.**

4. **Attention should be given at all levels of government to ensure that efforts to mitigate urban flooding reach areas that have the highest risk of flooding and cross all economic and social levels and that locally supported steps are taken to incentivize individual homeowner mitigation efforts.**

5. **In coordination with ongoing efforts to ensure that those at risk of flooding are aware of their vulnerabilities, FEMA, USACE, NOAA, USGS, EPA, and HUD, in collaboration with urban flood communities, should integrate urban flood risk communication outreach into their ongoing programs for riverine and coastal flooding and ensure that analysis of future conditions should include the impacts of climate and weather and future development.**

6. **States should consider integrating urban flood risk communication, mapping, and risk disclosure measures into real estate transactions in urban flood areas.**

7. **The Congress and the administration, in coordination with state governors, regional, local, and tribal officials, should develop appropriate mechanisms at the federal, state, and local level to fund necessary repairs, operations, and upgrades of current stormwater and urban flood-related infrastructure.**

8. **Congress should direct the administration to establish a risk identification grant program that enables communities to develop effective means of identifying the risks they face from urban flooding.**

9. **The administration should support continued research into urban flooding to ensure that the full extent of the threat is identified and that steps are taken to formulate solutions to policy and technical issues.**

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